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DEFENSE COMMUNICATIONS AGENCY

PLANNER'S GUIDE TO FACILITIES LAYOUT AND DESIGN FOR
THE DEFENSE COMMUNICATIONS SYSTEM PHYSICAL PLANT

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VOLUME 2

DCS SITE AND BUILDING INFORMATION

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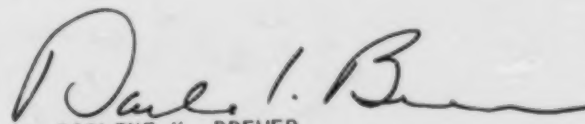
29 July 1985

DCA FACILITIES

A Planner's Guide to Facilities Layout and Design for
the Defense Communications System Physical Plant

1. Purpose. This Circular provides planning information, guidance, and criteria for the development of facility renovation, expansion, alteration, or new construction projects planned for the worldwide DCS physical plant.
2. Applicability. This Circular applies to Headquarters, DCA; DCA field activities; and military departments responsible for the planning and acquisition of DCS facilities.
3. Contents. To facilitate the use, updating, and expansion of the material covered, the Circular has been organized into three general divisions.
 - a. Volumes 1a and 1b provide the bulk of the information necessary to plan specific DCS facility types. All of the theoretically ideal data which needs to be considered at any of the stages of project development is contained in these first two volumes.
 - b. Volume 2 contains generic information which may additionally apply to specific facilities, depending on their location and importance within the DCS.
 - c. Volume 3 provides a series of case studies to demonstrate ways of applying the "ideal" guidance contained in the first three volumes with the practical limitations of the world in which the DCS must plan and operate.
4. Document Improvement. This is intended to be a living document, one which will mature with the evolution of the DCS. To accomplish this goal, comments or suggestions for improvement of the contents are encouraged, and should be directed to the Defense Communications Agency, ATTN: Code B212, Washington, D. C. 20305.

FOR THE DIRECTOR:


DARLENE K. BREWER
Colonel, USAF
Chief of Staff

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INTRODUCTION

1 Purpose of These Documents

The Military Departments (MILDEPs) operate Defense Communication System (DCS) facilities throughout the United States and the free world. These facilities must provide a high level of mission responsiveness to enhance the specific activity efforts of military service personnel. Also, since DCS requirements and communication equipment are constantly evolving, much flexibility must be designed into each facility.

The Defense Communications Agency Defense Communications Engineering Command (DCA/DCEC) desired to implement an optimal workstation and facility layout design handbook to assist planning, programming, and design personnel in increasing the environmental satisfaction of all DCS facility users. To this end, the U.S. Army Construction Engineering Research Laboratory (USA-CERL) was requested to survey, evaluate, and design prototype optimal workstations and total facility layouts for all personnel and equipment requirements. The objective of this effort was to develop optimal prototype space utilization and habitability designs for all DCS facility types. A research plan was started to: (1) determine all generic communication areas and space requirements, (2) analyze the mission responsiveness issues (efficiency, privacy, security, etc.) for the various workstations, (3) design an optimal layout plan for each space type, and (4) provide planning, programming, and design documents to assist in the development of all future projects. These documents would aid in designing new construction and in renovating existing buildings to meet current accepted requirements for the DCS facilities.

The handbook has been separated into three volumes, 1A, 1B, and 2. Volumes 1A and 1B contain facility information obtained from personnel who operate and maintain the DCS. Using input from several (7 to 16) persons about the same space, generic requirements necessary to accomplish the DCS activities in that space were determined. Therefore, Volumes 1A and 1B contain mostly new information from persons with several years' actual experience in a variety of existing DCS facilities and circumstances. Volume 1A has information about each space of each transmission facility type and Volume 1B has similar information about the spaces in switch and control facilities. Volume 2 contains information about extenuating conditions that also must be considered as part of the requirements for responsive DCS facilities--survivability, security, climate, construction components, site utilities, and similar factors. Most Volume 2 information came from existing documents (approximately 200) approved for use in DCS facility planning, programming, and design. All extracts from these documents are identified by a number at the end indicating the document and the page or section from which the extract was taken, e.g., "(9) 153" indicates that the extract came from page 153 of the source numbered 9 in the Bibliography.

These documents are designed to serve many types of facility project decision makers. Specifically, they are intended to aid facility planners, programmers, and construction project designers; they also should help DCS facility commanders to evaluate their existing facilities. These users require several types of facility information. Thus, information in this handbook can be used for specific design decisions for new construction or renovation, and for evaluation of an existing facility. For the first type of decision, once a communication requirement has been determined, these documents have the information required to determine the total area and separate spaces for operational sections in each major organizational unit. Next, optimal room areas are indicated to assist in dividing up the allocated square footage of each organizational unit. Finally, the individual workstations can be designed considering the demands on communications, electrical, and mechanical systems. For the second type of decision, this information is intended to allow DCS facility commanders to develop a continuing evaluation program for their facilities. The information is in a format that describes optimal workstation requirements, criteria, and guidance layouts; individual units can work toward these in a series of small-scale operations and maintenance improvement projects to improve the total facility operational effectiveness in performing the DCS mission.

These documents also provide DCS facility site planning concepts. The Department of Defense (DOD), DCA, and MILDEP communication command personnel can use this information to determine construction and/or equipment procurement needed to carry out the total communication mission. Readers interested in developing functional requirements for the 1391 documentation of a construction project should focus primarily on activity, personnel, equipment, and requirements columns for each space and on the space relationship diagram for each facility type. Readers interested in developing project designs should attend to the criteria, guidance, building components, and systems columns for each space and to the prototype total building design at the end of each facility type section.

2 Organization of the Information

The information in these documents is organized into data that apply to the following:

- a. Individual workspaces within organizational subsections of a communication facility.
- b. An entire DCS facility as an integrated whole.
- c. Recommendations for options to accommodate the special operational and survivability requirements for an entire DCS site.

The information is formatted space by space. For each component space, 10 types of data are presented:

1. *function*--statement of the overall reason for the space in a facility.
2. *policy and sop* (standard operating procedures)--regulations that define what must be done and how it should be done. The information is taken from documents such as service regulations, field manuals, and unit or installation procedure statements.
3. *issues*--data indicating how the work activities can be improved by alternative environmental conditions or trade-offs related to different ways of accomplishing functions at the facility.
4. *assumptions*--statements related to each issue; these recommend how the facility should be designed for optimal mission responsiveness over time. (Not all issues have these recommendations.)
5. *activities/personnel/equipment*--specifically what the functional operations are, who does them, and with what equipment that is not part of the building.
6. *requirements*--qualitative statements about what the building must be to provide optimal occupant/environmental interaction over time.
7. *criteria*--statements developed directly from the requirements list; these provide quantitative and/or qualitative measures to determine the proper design solution for an interactive building.

8. *guidance*--statements, sketches, and diagrams providing realistic advice based on design experience and case studies related to similar building spaces.

For each DCS facility type, a space relationship diagram is also presented to show the desired optimal adjacencies of all workstations and spaces for the particular facility. All information contained in the 10 categories is generic and relates to functions at DCS communication facilities. "Generic" means these functions are generally operational for any communication facility, no matter which military unit is involved. In progression, the separate spaces first were generated in terms of relating policies and SOP to the activities, personnel, and equipment required to accomplish a specific function. Next, requirements and criteria for the facility workstations were developed. Finally, planning concepts in the form of potential guidance related to specific building or exterior operational areas were generated. Thus, the requirements, criteria, and guidance provide the "optimal information" for mission activities. Relevant information about operation and maintenance (O&M) practices were obtained from discussions with military units, communication industry operators, construction researchers, and reviews of current periodicals and research literature. The information has been integrated into a six-page format for each functional area so that all information can be seen together, starting with the policies related to a particular function through space layout sketches and building component and systems recommendations. This organization should permit ready access and easy incorporation of applicable information into planning, programming, and design documentation by the various decision makers who develop DCS facilities.

3 Future Development of the DCS

As DCS changes to meet future demands, the transition will reflect an evolution toward current technology and concepts as well as increased commonality with civil systems and improved interoperability with other communications agencies. This theme is dictated by DOD's evolutionary acquisition system and by the economic realities of constrained DCS budgets. The constant need for expanded services demands that the design approach retain flexibility to improve as opportunities permit, yet competition for monetary resources insists on greater cost efficiency. Thus, there will be a need for balance as well as for facilities that support the evolutionary systems. (182) B-1

The main reasons for changing the baseline facilities are (1) deficiencies in the quality and reliability of power, (2) energy inefficiency, (3) lack of facility standardization, and (4) possible vulnerability to sabotage and EMP effects. Energy use at the DCS sites will continue to escalate the total cost to DCS. Power system improvements and power-saving steps can reduce energy expenditures, leading to many benefits in availability and reliability. Changes in DCS communications equipment will permit real gains within the total communications complex. With the size of equipment and power consumption reduced, new approaches to facilities and facility support become possible. Areas other than power, such as environmental control and building size, can be demanding with respect to heating/cooling requirements. Also, spectronics and facilities equipment can be designed on a system basis to take advantage of individual system characteristics. (182) B-2

DCS facilities thus will evolve in different aspects during future development. Several trends will be evident in this transition, as summarized below.

Transmission Media

Programs are available to change much of the DCS transmission media to digital techniques using a mix of media nodes. Pulse code modulation will provide the initial digital transition. Submultiplexers are programmed to replace old voice-frequency carrier telegraph equipment, and these will combine low-speed data input into a composite higher bit stream suitable for interfacing with 64 kbps data. Other time-division multiplexers are also being developed to support the digital DCS; bulk encryption is being developed for wideband links. Initially, wideband circuits between CONUS and overseas gateway stations will be encrypted, followed by encryption of the more critical overseas trunks. Commercially leased bandwidth will be bulk-encrypted at Government-owned technical control gateway facilities.

Early conversion from analog to digital transmission is a primary planning objective for DCS links because digital systems offer improved security performance, lower O&M costs, and pacing factors due to commercial, tactical, and data processing trends. Most terrestrial systems will be converted to digital ones by FY92, leading to bulk encryption, unstaffed stations, fewer modems, and simple interfaces to circuit switches. High frequency (HF) systems will be improved using adaptive techniques and new modems for digital operation. Economics will determine the timing of commercial terrestrial systems being digitized, but the long-term trend is toward digital transmission.

Wartime stress threats provide strong motivation for improved DCS connectivity. Interconnects with tactical, allied, and commercial systems thus are being considered to counter wartime conditions. A Joint Military Tactical Satellite System (JMTSS) is being considered to interconnect tactical systems with the DCS and to extend the DCS in wartime. Satellite systems, commercial as well as the Defense Satellite Communication System (DSCS), will be improved. Commercial satellites will offer multiple spot-beam antennas, higher operating radio frequencies, on-board TDMA switching, small earth terminals, and demand access. DSCS will acquire adaptive controls, channelized transponders, multiple-beam antennas, on-board processing, and extra high frequencies (EHF). Commercial systems, with increased commercial competition, will also offer attractive prices and route diversity as alternatives to Government-owned systems. (182) B-3

Satellite Media

Earth terminals served by the DSCS will number more than 600 by 1986. Among these terminals are the heavy, fixed variety and several small, transportable systems that will serve the ground mobile forces and special users such as the Diplomatic Telecommunications Service and the White House Communications Agency.

DSCS III space platforms will be operational in the mid-80s and will feature six transponders per satellite, multibeam antennas, channelized transponders, and adaptive power control. Two of the transponders will have 40-watt traveling wave tube amplifiers and the other four will have 10-watt traveling wave tube amplifiers. Antijam capabilities will become available with the AN/USA-28 modem and a spread spectrum multiple access (SSMA) modem for GMF terminals. The Jam-Resistant Satellite Communications (JRSC) program will field AN/TSC-86 terminals (with AN/USC-28 modems) near worldwide military command and control systems (WMMCCS) users, canceling their dependence on gateway satellite terminals. Higher frequency transponders (in the EHF range) can be expected for DSCS in about 1990.

Leased satellite service for INTELSAT will connect the CONUS to Europe and to the Pacific; DOMSAT will provide satellite service within

the Western Hemisphere (Alaska, Caribbean, Hawaii, CONUS). Leased satellite service will offer single- and multichannel, point-to-point, analog, and digital service and will be cost-competitive over distances greater than 1300 kilometers. (182) B-4

Terrestrial Media

Terrestrial transmission systems will be converted from analog to digital type when existing equipment requires replacement or when it is otherwise necessary to convert. Network time synchronization will be applied for digital control. Fiber optic cable will be used to replace wire cable in some local areas as requirements and cost benefits dictate. The Digital Radio and Multiplexing Acquisition (DRAMA) program will provide transmission rates to 26 Mbps and bulk encryption. In the 1980s, a low-speed, time-division multiplexer (LSTDM) will offer user-to-user digital communications in multiples of 32 kbps. Unstaffed repeater stations for transmission systems will become more numerous.

HF radio systems will be retained primarily for restoral and contingency use. Digital HF transmission is expected, possibly to 16 kbps per channel. Since there is no existing plan or program for DCS HF radio advancements, the model for future HF is existing HF installations such as Croughton (Air Force), Pirmasens (Army), and Naples (Navy). The far-term concept is to transform the DCS into a Defense Switched Network (DSN). The DSN will have integrated transmission, switching, and technical controls and will be decentralized (in contrast to the present system) for long-haul communications. The network, above the base and local levels, will treat a whole base and a high density/high population user locale as a terminal. Maximum use will be made of commercially leased services. Separate network facilities and identities for AUTOVON, AUTODIN, and AUTOSEVOCOM will not be possible. The only distinction between voice and data services will be found at the user's terminal. Other concepts that will drive equipment acquisitions are:

1. Digital wideband transmission facilities as more communications satellites are used.
2. Bulk encryption as digitization proceeds.
3. Automation of most media functions as minicomputers and microcomputers become integral components of transmission facilities.
4. Unstaffed facility O&M as automation proceeds.
5. Reduction in the number and size of the largest facilities as a distributed (nodeless) and automated system is implemented.

6. More automatic interconnect opportunities between single transmission media systems (U.S.-commercial-international), and between user terminals and multimedia gateway facilities. (182) B-5

Message and Circuit Switches

Within the DCS switched voice networks, the feasible union of AUTOSEVOCOM and AUTOVON services will be evident as AUTOVON becomes the primary carrier for secure voice services. The trend will first appear in the Secure Voice Improvement Program (SVIP), which will be the vehicle for introducing a secure voice terminal to replace AUTOVON four-wire stations. AUTOVON itself will evolve to exploit developments in commercial telephony. AUTOVON/AUTOSEVOCOM will primarily change to reflect dramatic improvements occurring in commercial digital circuit-switching technology.

Common-user record and data traffic needs for the near term will be met by the AUTODIN I message-switched network. However, by FY92, AUTODIN I will have been merged into the Integrated AUTODIN System (IAS). The IAS is being developed to define a DCS subsystem that satisfies the requirements of AUTODIN I users worldwide in the most cost-efficient way possible. The IAS must be flexible enough to allow increases in system capacity and the addition of new capabilities, should such changes be justified by developing requirements. It will ultimately be fully integrated and engineered on a terminal-to-terminal basis.

Although the near- and midterm DCS architectures provide for independent switching functions through a wide variety of DCS subsystems (AUTOVON, AUTOSEVOCOM, and AUTODIN I), the future DCS will be characterized by distribution of the switching function and integration of DCS subsystems. The capability to switch nonsecure voice currently is provided by AUTOVON, whereas AUTOSEVOCOM provides secure voice switching. Beginning in about 1985, these functions will be merged under the SVIP as described above. Similarly, the IAS is designed to combine the packet switching capabilities with the message data switching capabilities of AUTODIN I. The final integration of functions will occur during the transitional period between 1998 and 2005. The end result of the integration process will be a cost-effective DCS III network supporting distributed communications and a unified signaling structure. AUTOVON, AUTODIN, and AUTOSEVOCOM will no longer be separate DCS subsystems; instead, they will consist of terminal programs served by a distributed DCS III/DSN.

Other plans for the near future include thinning the AUTODIN I switch population, developing a common family of AUTODIN terminals, and completing deployment of the current generation of Automatic Message Processing Equipment (AMPE). AUTODIN I switches will be phased out, and

new elements (i.e., Inter-Service/Agency [I-S/A] AMPEs and Centralized Service Facilities) will be fielded. A major objective of the midterm architecture is to preserve continuity of existing network services throughout the transition from old to new equipment. To facilitate this smooth transition, functions unique to AUTODIN I ASCs will be reallocated to new IAS elements; for example, I-S/A AMPEs will be enhanced to include the functions performed by near-term ASCs. The far term will see increased integration of the IAS with other DCS subsystems and continued evolution to an all-digital environment.

Another traffic switching program that could have major implications for the future DCS (overseas) is the European Telephone System (ETS). This system consists of 140 switching centers to be installed during 1983-86 (in Germany, Italy, and the BENELUX nations) to replace the current Direct Distance Dial Network and other common user telephone networks in Europe. The ETS could replace the few AUTOVON switches programmed for retention in DCS Europe. The ETS also could be used as a preprogrammed (logic) switching capability for a completely new communications system concept called the "Integrated Transmission, Switching, and Technical Control" (ITSTEC). (182) B-6

System and Technical Controls

The overall trends toward automation and digitization are also apparent in technical control. The technical control improvement program is to provide more effective ways to control the DCS, especially in a crisis environment. The approach is to improve recovery/reconstitution response time by reducing dependence on manual control procedures and in turn exploiting, when possible, proven operationally oriented automated and semiautomated processor-aided procedures.

Several developments in technology can improve DCS recovery/reconstitution response time. The most important development is incorporation of technology in the DCS switching and transmission subsystems to facilitate subsystem-level controls, thus enabling recovery, reconfiguration, and interoperability. An example is the DSCS, which is evolving with increasing flexibility to dynamically manage and reallocate satellite resources in response to traffic requirements and stress situations. Similar capability to dynamically reallocate terrestrial digital transmission resources is also feasible. A second development is the emergence of the tactical Communications System Control Element (CSCE). The CSCE will provide the communications and processing resources for exchanging and processing timely management and control information throughout the tactical echelons. This system control concept has potential application in the DCS.

The major improvements anticipated for control capabilities during FY83-92 will likely evolve from six major ongoing control programs:

1. Worldwide On-Line (WWOL) system upgrade.
2. DCS System Control Improvement Program.
3. DCS Technical Control Improvement Program (TCIP), both manual and automatic.
4. DCS Voice Orderwire Program.
5. DSCS Real-Time Adaptive Control (RTAC).
6. Establishment of a Network Control Center (NCC) in support of DCS. (182) 8-9

Facilities

Facility designers and users will begin taking advantage of new technology aimed at their needs. The evolving DCS baseline will affect the needs for structure size, environmental control and power requirements, and proper grounding, bonding, and shielding.

The move to integrated circuitry by various elements of the DCS will have a profound effect on structures that house DCS elements. First, it will permit consolidation within buildings designed for retention. Although some modification within the structure will be necessary, parts of the building will be filled for other purposes, thereby lowering building maintenance costs. Functional consolidations will permit cross-utilization of manpower, reduce manpower-intensive communications-electronics (C-E) functions, and result in reduced annual DCS O&M costs. The move to smaller electronics will permit the use of smaller sites that are easier to secure and that have a reduced need for external utilities support. Although the next 10 years may see few new DCS sites, extensive modifications will occur at many existing sites. The need to acquire real estate is a major contributor to the utilization of present locations, since in many locales new land acquisition is nearly impossible. There will be a trend to standardize as facilities are built, modified, or leased. These standards will include concepts to increase the structure's flexibility in configuring or adapting to changing requirements. Consistent with efforts to improve the standards and flexibility of DCS structures will be efforts to improve the survivability protection against conventional warfare and EMP threats through the use of innovative construction concepts. These include using earthen covers or adapting standard buildings to DCS sites quickly. For the near- and midterm, the structure, other facilities, and equipment will be adapted and integrated more closely to reduce energy consumption, lower maintenance costs, and rely less on personnel.

As the DCS evolves, power systems that support the communications system will be improved to insure reliability in providing the quality of power required. The cost of commercial power is expected to continue

rising, so that the evolving DCS baseline will move toward alternative power sources when possible. The need for back-up power will remain and the rotating engines that provide it will be in the system into the midterm. However, diesel generator use should decline as onsite power becomes more practical using photovoltaic solar panels. At some sites that require large amounts of power, the reliable long-life diesel motor generator may supply the primary power.

By the end of the midterm there will be few exceptions to a total d.c.-powered DCS. This will increase efficiency and reliability by reducing the number of components in the system. It will also improve the DCS' ability to use renewable power sources such as photovoltaic solar panels, wind-powered generators, thermoelectric generators, and other power sources for which the output is generally d.c.

Renewable energy sources may not be practical in all cases. For example, there may be long periods of no sun or wind when a nonrenewable source must carry the load. Since during wartime a particular fuel may not be available, emphasis will be placed on developing and placing in the field systems that can use several different fossil or synthetic-type fuels.

As new facilities are designed or modified there will be more specific adaptation of the power source to the power requirement. The use of integrated circuits will, in general, require less power as will ancillary components such as environmental controls. Also, the practice to oversize the power system to accommodate possible expansion will be discontinued. The net result by the 1990s will be a savings in total power cost, including costs for fuel, commercial power, maintenance, and personnel to operate and maintain the equipment.

The energy crisis and the trend toward use of lower power dissipation electronics using integrated circuits has made it possible to eliminate complicated environmental control systems. The improved electronics can operate at wide ranges of conditions, thereby reducing the need for a tightly controlled air supply and permitting use of outside air. With the environmental controls eased, significant energy savings can be realized.

Integrated circuits permit the use of innovative packaging or building design to assist in environmental control and to lessen demands for energy. An example is the grouping together of high heat dissipation components, eliminating the need to cool an entire area. Environmental controls traditionally have been part of the building but as the DCS evolves, that trend will fade. As the communications complex becomes smaller, the environmental control system can be adapted to the communications equipment. Portions of buildings can be blocked off to insure that only the critical components are subjected to a precise environment, not the entire structure. Providing a determined

Integration of the environmental control system with the electronics, power system, and building will permit a more efficient operating unit and reduce environmental control failures. (182) B-12

Many DCS sites have inadequate grounding systems or systems in need of repair; however, the need for more attention in this area is recognized to provide better performance and protection against lightning, EMP, and similar phenomena. Improvement is expected to occur naturally as sites are reconfigured with new electronics. There are plans to rework grounding fully on a system basis at every station targeted for major change in electronics during the next 10 years. (182) B-13

Summary

This introduction has summarized the effects of technological opportunities, planned and programmed DCS trends, and nontechnical/non-programmatic considerations 10 to 20 years into the future, including the DCS architectural concept ITSTEC with respect to the 1990s DCS requirement for facilities support. First, the waves of modern, complex, and sophisticated C-E equipment on the commercial market, such as powerful microprocessors spawned from large-scale integration (LSI) technology, offer more cost-effective use of switches, concentrators, and multiplexers within the DCS. The fringe benefits that generally accompany microelectronics are improved reliability of hardware, inherent modularity, and reductions in physical size and energy demands. In fact, some electronic switching systems in the Bell System now operate at such low power levels (less than 6 volts and at a few milliamperes) that conditioned power and shielding become stringent facility requirements. Microprocessor technology will be reflected in DCS C-E equipment and in facilities equipment over an extended period of time extending well beyond 1990. This is because the motivation to make basic changes to the DCS must come through very fundamental, strong reasons. To date, the motivation behind DCS assimilation of modern technology is not a need for technology, per se, to fix a broken system but, the need to find ways to provide existing communications at lower annual O&M costs.

Second, driven again by economics and by much activity in the commercial sector, there will be increased installation of satellite ground terminals associated directly with individual (community) access areas (e.g., single bases and large military populations such as those found in the Washington, DC, and Tidewater, VA, areas). A basic satellite architecture will emphasize direct interconnection between access areas and will deemphasize terrestrial connectivity and switching via rigid backbones that are manpower-intensive. Since military use of satellite communications requires the same measure of survivability and resistance to radio signal jamming as required of any other communications media, it is expected that, as an expedient, connectivity between access areas will be affected first through the switched public networks. This arrangement will continue until satellite communications are hardened

enough to make the media viable in war time. In either a public or a military satellite network, without benefit of a Government-furnished backbone, a more unified strategic-tactical DOD switched communications system will evolve. A system like this will represent a second generation DCS that involves real-time dynamic allocation of wideband, digitized transmission channels through DCS switching and processing functions within or adjacent to access areas.

These functions have been defined within the ITSTEC conceptual architecture that could be implemented during 1984-94. The significance of the ITSTEC concept to this study of facilities requirements is that an entirely new, different DCS station is suggested that combines DCS functions which, to date, have generally been supported by separate structures, power plants, environmental controls, and G-B-S installations.

The third major condition influencing facilities requirements along new directions is the development of new perspectives concerning the DCS mission. These perspectives are again driven by economic imperatives to obtain the most utility from finite resources. Over the past 16 years, budgetary constraints have reduced the availability of Army and Air Force tactical communications in-theater assets. Consequently, there is now increased dependence on the in-theater DCS to support U.S. combat forces in the initial phases of any conflict overseas. However, the DCS was not originally designed to be a wartime system. Therefore, a major underlying thrust driving new DCS architectures is "design-for-war."

The DCS research and development strategy for "design-for-war" is to configure/harden certain DCS subsystems based on criticality of the DCS users' needs. This strategy was adopted because a composite DCS resistant to all threats is neither technically feasible nor economical. Therefore, improved DCS readiness will be achieved by developing countermeasures against specific threats in specific areas of the world. In Europe, the all-time threat to the DCS is sabotage; the overt hostilities threat is the collateral effect of conventional munitions delivered by aircraft. At the same time, there is a measured approach to DCS wartime readiness and an increasing concern with the annual DCS costs of providing day-to-day peacetime communications. Fossil fuel and manpower are the most inflationary of the annual recurring costs in MILDEP budgets. With a theoretical monetary lid on how much a peacetime DCS is allowed to cost, it has become necessary for DOD, DCA, and the services to find cheaper alternatives to fossil-fueled power and to find less manpower-intensive ways to support DCS O&M responsibilities. (182) B-57

4 Updating DCS Facility Information

The facility information contained in Volumes 1A, 1B, and 2 is intended to be updated every 2 years as requirements for DCS transmission, switch, and control facilities evolve. Three aspects of the DCS have been and will continue to be the basis of the need for dynamic, evolving DCS facilities:

1. The continuing development of communication transmission, switch, and control equipment--especially the expanded use of computer-automated devices to augment existing capabilities.
2. The refinement of alternative energy sources to be more cost-competitive and less vulnerable to existing commercial power with diesel generator standby back-up.
3. The development of improved security and survivability components that will enable existing DCS installations to become less vulnerable to sabotage and attack threats.

As the existing facility information in each edition of Volumes 1A, 1B, and 2 is used for specific projects that are constructed and operated, it is intended that facility evaluations be carried out to provide feedback to the documents. This feedback can be either additions to provide more comprehensive facility information or deletions to eliminate information that becomes outdated. Over time, the volumes can become handbooks of the best current information available.

5 Example Projects--Retrofits and New Construction Case Studies (Volume 3)

As part of the development of these facility documents dealing with the application of generic optimal DCS space information, several case study communication stations were designed to be constructed, implemented, and evaluated. These were done through the auspices of the MILDEPs responsible for DCS facilities. The reader is invited to carefully review the floor plan drawings and other section and elevation diagrams to understand the optimal capabilities and flexibilities of the design solutions. The reader is then referred to the generic design information for each space in Volumes 1A, 1B, and 2.

By using the examples presented in Volume 2, which have been derived from information on the various DCS facility types in Volumes 1A and 1B, the reader should be able to develop an optimal layout design for any communication station. Special conditions (survivability, security, etc.) that also must be considered when designing DCS facilities are referenced back to Volume 2. Therefore, the examples are intended to be studied to provide readers with an awareness of how the comprehensive generic facility information in Volumes 1A, 1B, and 2 can contribute to specific projects--they are not used as standard design solutions to be copied.

Of the examples, some are OCONUS new construction projects, some are OCONUS survivability retrofits at existing DCS sites, and the remaining ones are retrofits that improve operational conditions in transmission, switch, or control spaces of existing DCS buildings.

**SB1
Site Planning and Development**

References:

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SITE PLANNING AND DEVELOPMENT

function

To select the best available site from among potential candidates and to insure proper installation to meet the facility's mission.

policy / sop

All facilities shall be designed to have a minimum useful life of 15 years when exposed to the ambient environment of the selected site(s). Facilities that support technical equipment shall be designed for 24-hour-per-day operation, 7 days a week.

Existing, locally available power must be adequate to meet the total operational requirements of the facility. A power system must be planned if locally available power is inadequate. (1) 7. See SB3.

Adverse geological and weather conditions shall constitute reason for rejecting a potential site. The nature of the terrain, surface and subsurface, as well as local seismic conditions shall be considered thoroughly to assess the degree to which site components and functions may be partially or totally degraded. (9) 5.1.3.1.2.8

Defense Communication System (DCS) sites follow applicable environmental regulations. Installations will comply with appropriate Federal, state, and local regulations and when located in foreign countries will follow regulations of the host country. Water quality will be at the more stringent level of the host country or the United States. The construction must also comply with the host nation's air and water pollution regulations. (86)

Army and DOD regulations which are pertinent include: AR 420-46, AR 200-1, and AR 210-30.

In accordance with Public Law 91-190, E.O. 11507, and E.O. 11514, in developing the design for projects, necessary measurements shall be taken to eliminate or minimize degradation of the environment during construction operations. (93) 2-7

The survey team is required to investigate the available supply of labor, equipment, materials, and local contractor capabilities. Sufficient data must be collected to provide information for an accurate construction cost estimate, to establish the adequacy of local materials and labor, and to provide information to the design forces to enable them to design to meet the local conditions. (31) 2-11

policy / sop

Provisions of utilities essential to efficient operation and of adequate size to serve future requirements shall be considered in the early planning stages to avoid conflicts in the design and layout of the various utility lines. Planning of utility lines shall take into consideration conditions such as: (1) utility easements or right-of-way; (2) location, size, and elevations of sanitary sewers, storm drains, or open drainage channels, drain inlets, and manholes; (3) location, elevation, and size of water, gas, heat transmission mains, and underground electrical service; (4) location and size of overhead electrical service, street lighting, and telephone lines including pole and manhole locations. (Refer to SB7 for security considerations.)

Underground lines shall be located so that minimum effort and cost will be required to excavate the lines for maintenance. Normally, underground utility lines of all types shall be located along streets, roads, or utility strips and not under roads, sidewalks, parking lots, paved terraces, and other paved areas. Underground utility lines, mains, and conduit shall be located at the minimum depth necessary.

issues and assumptions**1. Environmental conditions**

The environmental conditions to which the earth station will be subjected are important considerations in facility design and may be reflected in requirements for the construction of site buildings, shelters, and antennas. (1) 10

2. Existing site analysis

The review of existing communication facilities and site layouts can provide insights in evaluating the suitability of a potential site for a particular mission. See Volume 2, Case Studies, for examples.

3. System integrity

Of foremost importance in the evaluation of a potential site is the integrity of the system. Above all other considerations, the system must function within the parameters established in the documents authorizing the system and specifications included therein or developed subsequently. Since a chain is only as strong as its weakest link, any site which compromises the system parameters degrades the entire system. Economics, logistics, etc., of a particular site very often must be forfeited to satisfy the overall system requirements. (31) 2-12.

Maximum signal strength and clarity are desired at each individual site. The minimum acceptable requirements are dependent upon the overall system requirements. Although maximum performance is desired, the expenditure of extra funds or efforts to make a site better than the system requirements must be justified. (31) 2-12

4. Time versus site acquisition

Regardless of the qualifications of the site, it is valueless if it cannot be made available in time to meet the program schedule. The procedures for obtaining lands from government agencies or from private ownership may be lengthy and time consuming. The approximate date on which the site will be available should be determined during a site survey. An alternate site should be sought if it appears there will be insufficient time to build on a site or to install a facility after the land becomes available. (31) 2-12

The inclusion of alternate sites and pertinent information can save the cost and time of an additional field trip if, for any reason, the site selected proves to be unsuitable or unavailable. (31) 2-6

5. Remote site versus logistics

With the large number of U.S. military establishments throughout the world, the logistics problem for outlying sites has been greatly reduced. However, a remotely located site will still present a support problem and if the site is found to be too difficult to support, the selection of an alternate site should be considered. (31) 2-12

issues and assumptions**6. Site suitability**

One of the first things to do upon reaching a site is to perform a site reconnaissance for making a preliminary evaluation of the site to determine its overall suitability. To avoid wasted effort in case the site should prove to be obviously unsuitable for any reason, this preliminary evaluation should be made before any other work is done. (31) 2-1

Easy formulas for the final selection of a communication facility site do not exist. It may be an obvious choice, with the site survey serving merely to corroborate the selection, or it may be a difficult task involving the evaluation of all factors bearing on the selection.

7. Real estate availability

There are usually many factors limiting the number of suitable terminal and relay sites. Some of these factors are large bodies of water, blockage by terrain or terrain clutter (without using unacceptably high towers), prior use of suitable sites, political boundaries, potential interference with other radio systems, local zoning regulations, ease of access, and environmental aspects. Site availability investigations should include a check into possible site security problems. Particularly, unattended operation increases the possibility of theft, vandalism, or other damage and may require special and substantial considerations. Site development costs will generally be substantially lower if a site can be found on Government-owned lands, rather than on private property. (9) 4.1.6.

8. Electromagnetic Compatibility (EMC):

Electromagnetic Compatibility (EMC) is the ability of C-E equipments, subsystems, and systems to operate in their intended operational environments without suffering or causing unacceptable degradation because of unintentional electromagnetic radiation or response. Electromagnetic Interference (EMI) is the phenomenon resulting when electromagnetic energy causes unacceptable or undesirable responses, malfunction, degradation, or interruption of the intended operation of electronic equipment, subsystem or system. The term radio noise is reserved for emanations other than signals. (197) 1-1

requirements	criteria	commentary
SITE IMPACT 1. Site selection in relationship to the facility land use.	1. a. RFI/EMI environment The ambient RFI/EMI can have an impact on site selection due to its degrading effect on the system's performance. b. Land area required c. Defensibility/site hardening When survivability is important to a facility's mission, the facility should be able to withstand environmental conditions made hostile by weather, or by conventional or unconventional warfare. (See SB5 and SB8 for further information.) d. Antenna locations/orientations Antenna spacing and siting receive first consideration, with the location of the building determined in relation to the antenna(s). In many types of antenna systems, the topography and natural environment are vital factors in the transmission and receiving capabilities of the site. Large-scale, earthmoving operations are costly and may not be possible. The topography must be suitable for construction. (31) 2-12 e. Adjacent property easements Very often there may be radio interference or physical interference, such as trees, etc., on adjacent properties. Easements or modifications may have to be made to these properties to enable a communication site to function properly. Easements for access roads, power lines, and communication lines also may be required. If the necessary modifications or easements cannot be accomplished or secured within the time allocated, the site may lose its value to the system. (31) 2-13 f. Adjacency of "reaction forces" The availability and location of reaction forces shall be considered in the selection of a DCS site. The nature of the terrain separating the reaction forces from the site and the mobilization and transportation time required by the reaction force prior to arrival at an alerted site shall be major in the selection of a site. (9) 5.1.3 g. Future expansion considerations Additional value should be placed on a site that can be expanded over one that cannot be expanded. (31) 2-13	The rapid advance of technology has increased not only the number of electrical equipments, but also their complexity. Thus, the effectiveness of performing almost any single ultimate function is now usually dependent on the efficient performance of many other functions. Increasing density of equipment to perform these functions greatly increases the possibility of degradation by EMI in performance by undesired electromagnetic interactions. Examples of recent technological developments which have increased the possibility of interactions include: a. Miniature integrated circuits which result in high component packing densities. b. Increase component susceptibility because of higher sensitivity. c. Use of wider bandwidths in equipment design. Possible consequences of performance degradations caused by electromagnetic interference include: a. Mission abort b. Message inaccuracies c. Message repeats or delays d. Navigational errors e. Failure of logistic support f. Reduction of system availability g. Movement surveillance under combat conditions. (197) 1-1 All potential communication station sites need to have an electromagnetic survey made and analyzed before any design work is started. Several recent projects have been delayed (or even terminated) when EMI conditions were discovered after many months of planning and design and been started.

requirements	criteria	commentary
2. Site topography for the DCS facility building and antenna structures.	2. a. Suitable landforms When reviewing potential sites, the topographic maps should include all physical features within and beyond the site boundaries which could affect the electronic suitability of the site. All structures, natural objects, heavily wooded areas, and isolated trees on the site should be located on the map. (31) 2-7 b. Susceptibility to flooding The site will be examined to determine potential flooding. Flooding may occur from a river, stream, or intermittent stream or ravine which is dry except during a rain storm. Melt water from high mountain areas can also cause flooding, including destructive flash floods even on sunny days if a storm is taking place far away in the mountains. Such areas should be avoided: no structures should be built in such areas. c. Visual/noise absorption ability Many landforms have characteristic "closure" or "openess." These affect the privacy and can decrease the notoriety associated with the DCS facility, where desired. In addition, increasing landform closure can decrease the accessible proportion of the sky for communication transmission and reception or limit the options available for microwave tower siting. d. Landform stability The materials of which the landforms are composed can determine their stability. Even stable (e.g., schist) landforms can be associated with physical processes which make them particularly unstable (e.g., a clay cliff adjoining a river may be particularly susceptible to sliding or slumping). e. Erosion susceptibility by wind Landforms established by wind are also likely to be eroded by wind (e.g., loess). At sites which are unprotected (e.g., mountain tops) or areas where high winds are characteristic (open plains like the prairies of the Midwest) wind erosion will deface the land, or the load the wind carries, when deposited on equipment, will cause premature failure due to abrasive wear.	

requirements	criteria	commentary
	f. Bearing weight ability Depends on the soils at the site, their characteristic moisture content, their underlayment and the slope of the land surface. However, before a detailed soils survey is done at a site, some attention must be paid to the site's bearing ability. The landforms are often associated with soil types (at the generalized "association" level). Thus determining a landform type can give a planner a rough estimate of a site's ability to support structures, particularly those structures which will tend to concentrate weight onto a small area (e.g., an antenna pad). g. Shrinkage-swell amounts Depend on the characteristic moisture content of the soils at the site. However, before a detailed soils survey, some attention must be paid to the site's shrinkage-swell amount. The landforms are often associated with soil types (at the generalized "association" level). Thus determining a landform type can give a planner a rough estimate of moisture load in the soil. Ignoring this may result in cracked foundations and water leakage. h. Frost heave potential Depends on the soils at the site, their characteristic moisture content and the annual and diurnal variations in temperature when near the freezing point. However, before a detailed soils survey, some attention must be paid to the site's frost heave potential. The landforms are often associated with soil types (at the generalized "association" level). Thus, determining a landform type can give a planner a rough estimate of the feasibility of that site to remain stable when temperatures vary near freezing. Ignoring this may result in cracked foundations, water leakage, and rough and deteriorated roads after only a few years of use. i. Site modifications Landforms are natural objects created over a long period of the earth's history. If the site has already been modified by some previous construction, including historic or extensive prehistoric works, the site may not now carry on the critical natural characteristics. In such a case, only on-site, detailed studies will yield accurate information.	

requirements	criteria	commentary
3. Site characteristics for the DCS operational activities, equipment, and maintenance.	3.a. Soils/bedrock Soil and foundation conditions shall be investigated to assure suitability for economic excavation, site preparation, building foundations, utility lines, grading, and planting. Bearing capacity tests shall be made to assure stable and economical foundations for buildings and other structures. (93) 4-4 b. Conductivity The soil conductivity is important for protection of the facility and its related equipment. (See SB4--"Grounding, Bonding, and Shielding" for further guidance.) c. Vegetation Landscaping and ground cover shall be provided only to the extent that they reduce site maintenance. (92) 12.1-11 d. Clearing of natural vegetation Vegetation provides much support to the stability and desirability of the site. It may provide wind protection, animinity where desired, and noise modification. Roots hold soil together, support soil formation, circulate nutrients, aerate soils, and moderate moisture extremes. Branches and leaves provide shade, moderate temperate extremes, and decrease wind and wind erosion. Further, it is easier to preserve existing vegetation than to remove it and try to establish new plants. A natural plant is where it is because it is very suited to be there. Finding a better replacement after nature has had centuries to experiment to find the optimum candidate is not very likely. Thus, it is best to leave natural vegetation undisturbed whenever possible. e. Dust generation Landforms established by wind are also likely to be eroded away by wind (e.g., loess). The load the wind carries, when deposited on equipment, will cause premature failure due to abrasive wear or will cause a loss of visibility resulting in safety and/or traffic problems. In areas particularly susceptible, the problem can be decreased by planting vegetation, by spreading on the surface water, oils (where allowed), or environmentally safe chemicals. Avoidance is an easier, less costly solution.	

requirements	criteria	commentary
4. Site circulation for the DCS equipment operational activities.	f. Ease of utility layout Is largely determined by the depth to bedrock (simply, it is easier to dig out soil than rock). Some landforms have deep soils, where bedrock is not present at or near the surface, while other landforms are surficial rock. Between these extremes are bedrock of various depths or landforms which are intermixed with rock or which are relatively soft rock. This concern largely is equivalent to the difficulty of digging a trench. 4.a. Access for logistic support In selecting a site, logistic support needs to be examined for ease of access during survey, installation, and operation phases. 1. Roads 2. Parking and servicing site vehicles 3. Hardstands at vehicle wash racks b. Personnel walkways Personnel walkways should be constructed within the facility boundaries to allow maintenance personnel free movement and easy access as they perform their duties. (1) 25 c. POV parking Private vehicles should be parked in a designated area outside of and not closer than 30 feet from the perimeter fence. Vehicles should not be authorized to park within 30 feet of a secure area or adjacent to critical components. d. Perimeter control See SB7--"Security Systems."	

requirements	criteria	commentary
3. Water distribution for building and site fire protection.	3. a. Storage and pressure See Guidance. b. Site distribution systems See Guidance.	
4. Maximum water conservation practices.	4. a. Water reuse options See Guidance. b. Conservation devices and system equipment 1. Toilet alternatives. 2. Toilet retrofits. 3. Water conservation devices.	
5. Accommodation of site groundwater and drainage conditions.	5. a. Analysis of surface and subsurface ground water and soil conditions A proposed site must not be susceptible to flooding and must be protected against heavy and sustained precipitation by adequate natural drainage. (38) 3-8 b. Susceptibility to change in water table depth Will limit the depth to which a planner may go in setting out underground utilities and sub-terrain foundations and basements. In planning, the worst case basis should be assumed, that is, planning will be limited by the high water table level. In addition to whether or not utilities can be established, there is the consideration of whether they should be established. Where sanitary sewage systems can be built, if the water table occasionally rises to the level where leaking sewage contaminates the water table affecting potability, not only the feasibility but the wisdom of the decision needs consideration. Where potable water is in short supply (arid areas and coastal areas surrounded by salt water) the importance of this factor is increased. Water table depth can be changed if the surface on which it stands (as for a perched water table or the aquifer's natural conduit--the vessel or "pipe" which holds it) is punctured by drilling or deep earth removal. In such a situation, the water will leak out just as if it were in a bowl with a hole near the bottom. Some landforms have these qualities more commonly than others.	

requirements	criteria	commentary
	c. Susceptibility to change in surface water May mean a decrease in the original supply by withdrawal (for drinking water or watering vegetation), interference with or diversion of a natural drainage way, or interference of the ability of the ground water recharge system (e.g., covering the recharge area with a concrete parking lot). d. Susceptibility to change in ground water flow See paragraphs c and d above. Ground water flows in the same way surface water does, only more slowly and through soil or rock. Changing this flow may affect water availability and quality downstream in the same manner as surface water. e. Erosion susceptibility by water Water erosion can change water quality, water amount, soil productivity, etc. Erosion susceptibility is determined by surface type (e.g., soil), slope, length of slope, vegetative cover, climate, and intensity of rain or water input. f. Ease of sedimentation Is the result of water-eroded materials settling in water courses. It is determined by the susceptibility to erosion, the distance of the low point (the stream or sedimentation basin), the velocity of the stream (a fast-moving stream will carry larger particles away and so be less likely to have high sedimentation), and the size (area) of the low point. g. Run-off based on slope, soil type, and vegetative cover Greater run-off increases likelihood of erosion, sedimentation, flash floods, and economic damage. Run-off increases as the slope increases, as slope length increases, as vegetative cover decreases, and as soil type changes.	

requirements	criteria	commentary
WASTEWATER IMPACT 1. Wastewater sanitary sewer system for DCS communication system equipment and personnel activities.	1. a. Determination of wastewater sources and rates of quantities produced Required treatment is determined by influent characteristics and the treatment process which produces an acceptable effluent. 1. Personnel activities. 2. Equipment/vehicles. 3. Expansion. b. Site variables See Guidance. c. Susceptibility to ground water pollution Ground water is the source of much potable water and flows underground to discharge areas (springs, streams, lakes). Normally, the soil cleans and decontaminates water so that polluted water is often purified by the soil by the time it reaches the ground water. Susceptibility increases where soils do not purify, where percolation rates are too fast for purification to take place (gravelly soils), where materials input are in too large a volume for natural processes to occur, where materials input are hazardous in very small quantities, and where the water table is near the surface or near the pollution sources. 1. Landform categories. 2. Portawasher.	
2. Wastewater treatment processes.	2. a. Treatment regulations and requirements The primary design goal for any wastewater treatment plant is to meet or exceed all effluent and water quality standards. b. Wastewater treatment systems Every site has its own set of design parameters. The system should be optimally engineered from the host of alternatives to achieve the most cost-effective and appropriate solution. c. Site constraints See Guidance.	

requirements	criteria	commentary
	d. Conservation options If water shortages are a concern, specialized alternatives such as composting toilets, vacuum systems, or graywater recycle systems should be examined. See also "Water conservation practices." 1. Composting toilets. e. Special waste disposal 1. Special regions (see SB9--"Climate Conditions"). 2. Chemical, biological, radiological (CBR) decontamination (see SB8--"Survivability Protection").	

requirements	criteria	commentary
ENERGY IMPACT 1. Orientation of DCS building and site relationships for optimum energy conservation.	1. a. Elements of occupant comfort See Guidance. b. Building location/shape/orientation See Guidance. c. Wind impact See Guidance. d. Solar impact See Guidance. e. Humidity/temperature impact See Guidance.	

guidance SITE IMPACT/1 Site Selection**1.a. RFI/EMI environment**

Electromagnetic interference (EMI) results when electromagnetic energy causes an unacceptable or undesirable response, malfunction, degradation, or interruption of the intended operation of an electronic equipment, subsystem, or system. (87) 4.8

Particular emphasis should be placed on establishing the maximum signal levels of any radiofrequency signals existing within the receiver frequency band. If any significant signals are found, calculations should be made to establish if their field intensity and modulation characteristics will cause unacceptable degradation of the facility's performance. (1) 8

EMI can arise from both natural and man-made sources. Natural sources such as lightning are geographically widespread. Man-made interference usually affects only limited areas close to the source. (87) 4.8.3

Isolation and location of a source of interference is necessary before effective action can be taken to eliminate it. To determine the source, it is usually necessary to find out how the interfering energy is being transferred from the interferer to the victim equipment. The two basic means of transfer are conduction and radiation. (87) 4.8.5

Interference by conduction can occur when two separate circuits have an element in common. Voltages from one circuit, present in the common element, affect the other circuit. A physical connection is unnecessary between the two circuits. Voltages in a wire can be transferred into another wire in proximity because of capacitive or inductive coupling. (87) 4.8.5.1

Radio equipment is designed to transfer information by radiation, or wave propagation through space. However, some types of equipment radiate unintentionally. Consequently, unwanted radiation finds its way as interference into receptors for which it was not intended. Frequency planning, together with bandwidth and power limitations, usually minimizes this interference. (87) 4.8.5.2

A knowledge of these transfer mechanisms is useful as a starting point in trying to locate and eliminate sources of interference. It is important to establish how interference is entering a receptor, as well as where it comes from, because the nature of the transfer mechanism often determines what remedial action can be taken. One of the most frequent instances of a common physical connection is in the grounding systems. A properly designed, installed, and maintained signal ground subsystem will reduce most interference. (87) 4.8.5.3

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Although a particular installation cannot always avoid being the victim of externally generated interference, much can be done within the station to prevent it from receiving or transmitting interference. Two of the most important factors in avoiding or minimizing EMC problems are knowledge of the station or facility and the capacity to speedily detect any abnormalities. Operating personnel should know normal meter and indicator readings, normal signal sounds, and normal visual representation of signals on instruments such as cathode ray oscilloscopes and spectrum analyzers. This requirement should be coupled with a thorough familiarity with all aspects of station configuration, and expertise in operation and maintenance procedures. Accurate station logs and performance records for channels and systems should provide invaluable data on past problems, which may throw light on current problems. (87) 4.8.6

Each of the three services has agencies to conduct EMC and EMI field and desk studies in accordance with applicable regulations. Additionally, the DOD Electromagnetic Compatibility Analysis Center (ECAC) at Annapolis, Maryland, provides assistance to users of all services. (87) 4.8.8

b. Land area required

The land area "available" is a greater determiner of site design than land areas "required." See Monte Vergine, Italy, and Feldberg, FRG, case studies in Vol. 3 for examples of this particular design restraint.

c. Defensibility/site hardening

The selected site shall be capable of being graded flat and cleared of all obstructions and vegetation to afford full fields of view and fire to defending site personnel. A trade-off is necessary with satellite communications stations because optimal signal-to-noise ratios are obtained by placing the facility in a valley or depression.

Sites shall be located such that the entire site is level with or higher than surrounding territory for site defense considerations. The grade of the summit on which the site is located shall not be sufficiently severe to offer an intruder any reverse cover or obstruct in any way a defender's full field of vision and fire. All these considerations shall apply also to the site access road.

guidance SITE IMPACT/1 Site Selection

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The DCS site shall not be surrounded or abutted by any natural or man-made features higher in elevation than the ground level of the site itself because of the advantages which would accrue to hostile forces in seizing these features to attack the DCS site.

d. Antenna locations/orientations

Foundations and support structures should be provided for antenna erection. Details of fixed site antenna support foundations are found in the applicable drawings provided by the antenna support manufacturer. (87) 4.3.3.5

A typical site layout should make the equipment building the center of site operations. The antenna structures should be placed as close to the equipment building as possible, consistent with design codes and standards to minimize the transmission line lengths required between equipment and antennas. (2) 5-5

Antenna installations require a clear area with a suitable radius for that particular antenna. This clear area shall be suitable for all-weather operation of heavy construction equipment such as cranes. (23) 3

The length of the waveguide run is important to the system's performance and should not exceed the manufacturer's recommended length. See Vols. 1A and Vol. 1B for specific antenna requirements.

e. Adjacent property easements

An extended cleared area at least 9 meters wide shall be maintained outside the perimeter fence through the use of chemicals or routine ground maintenance. The cleared area shall not have any obstacles, topographical features, or vegetation higher than 20 centimeters. Where possible, topographical features and obstacles shall be removed to permit visual or enhanced visual (binoculars) assessment of access road sensor alarms. (9) 5.1.3

f. Adjacency of "reaction forces"

The reaction force or response force consists of guards, security personnel, or operating personnel whose purpose is to intercept or delay an intruder through the use of force, including lethal force.

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The response time is the time required for the response force to bring adequate force to bear upon intruders so that no further damage is done to the site. Response time is measured from the time an alarm is assessed as requiring a response. In evaluating security measure effectiveness (including the stationing of security forces), response time should be less than the delay time resulting from security measure implementation.

g. Future expansion

All DCA sites may be subject to expansion requirements and must be designed accordingly to facilitate future growth.

2.a. Suitable landforms

The best terrain around a transmission facility would be relatively flat to preclude extensive site preparation. The main concern is that the horizon profile, in the direction of the antennas, should be free of obstructions. Each antenna system (SC, LOS, TS, and HF) has a set of particular requirements that dictate site suitability and conditions for operation. All except HF require proximity to the communication building for further efficiency. (See Volume 1A, "Transmission Facilities" for further guidance on requirements imposed on the site by the antenna system.)

Since the antennas can be quite large, height limitations imposed by airfield clearance requirements and local zoning restrictions need to be investigated during the siting process.

The site must not be susceptible to flooding and should have adequate natural drainage. Storm water run-off calculations should be based on 50-year design frequency. (1) 25

b. Susceptibility to flooding**1. Wind laid**

Sand dunes - Along the coastal areas are sometimes inundated by high winds and hurricanes.

Loess - No comment.

2. Water laid

Flood plains - High susceptibility since flooding is a natural process by which a river adjusts itself to increase capability.

Terraces - Often raised above the common flood levels with good soil and drainage characteristics.

Deltas - Inappropriate due to their high susceptibility to flooding, with some areas being inundated with every high tide.

guidance SITE IMPACT/2 Site Topography

3. Alluvial

Alluvial fans - Flooding can be often and intense, carrying water from the mountains to the valleys in flash floods. The force can be great enough to move large buildings.

Valley fill - Susceptible to flash floods but much less than alluvial fans.

Continental alluvium - Low; susceptibility to flash floods possible in some areas, but not usually.

4. Fresh water deposits

Lake beds and playas - High susceptibility, as the water table will occasionally surface and nearby ravines have the potential for flash floods.

Organic deposits - Likely to have the water table surface.

5. Marine

Coastal plains - Not usually susceptible to floodings.

Beach ridges - Little susceptibility except for those right next to the water side, which are formed by the deposition of materials by water body during a storm. The high point is the highest elevation reached by the water. Behind this, ridge flooding is unlikely. More ridges further away from the first indicate high storm levels from previous times when the mean water level was higher.

Tidal flats - High and continuous. The conditions are generally bad for structures and these areas should be avoided.

6. Metamorphic

Slate - Not usually a problem.

Shist - Not usually a problem.

Gneiss - Little; however, a spring high water table will cause local areas of ponds and wet spots.

guidance SITE IMPACT/2 Site Topography

7. Glacial

Till - Not great although water table may surface at times.

End moraines - Ponding and water table surfacing (ground moraines) possible.

Drumlins - None.

Eskers and kames - Slight.

Outwash - Slight; absorbs large amounts of water.

Lakebeds - Water table surfaces yearly but no flooding occurs unless it is closely associated with a large river.

Permafrost - In the spring, the surface of ice will thaw but will be underlaid by the frozen soil. Thus, the water cannot drain down through the soil, only over land. Since the drainage patterns in permafrost areas are poorly developed, the results are large areas of standing water a few inches deep. Flooding occurs only where the drainage pattern is developed enough to concentrate this water. This only rarely occurs.

8. Igneous

Granite - Minimal.

Basalt flows - Not usually a problem.

9. Sedimentary

Sandstone - Not usually a problem.

Shale - Not usually a problem.

Limestone - Not usually a problem.

Interbedded sedimentary - Not usually a problem

Coal - Not usually a problem.

C. Visual/noise absorption ability

1. Wind laid

Sand dunes - The drainage is nonintegrated, so there are many areas of negative drainage which provide high visual absorption. Often there is little vegetation so this contributes only slightly.

Loess - No comment.

guidance SITE IMPACT/2 Site Topography
2. Water laid

Flood plains - The land is basically flat, so only the vegetation has any absorption effect. Therefore, clearing has a large impact here.

Terraces - Because of their rough nature and excessively drained soils, they are often in forest cover so that they are not terribly sensitive. The good view from the terrace edge over the accompanying plains is an opportunity which should be investigated.

Deltas (birdsfoot and arc) - Flat areas but often with much absorptive forest; relatively insensitive if handled carefully. More sensitive as understory becomes more sparse.

(Estuarine) - Extremely high sensitivity as they are very flat with no obstructions. Any structure placed here will be extremely visible.

3. Alluvial

Alluvial fans - Little vegetation and positive curvature of landform give high visual sensitivity; most structures will be seen.

Valley fill - There is a certain amount of closure in the valleys between fans looking in a direction perpendicular to the water flow direction at its source, but otherwise the vegetation is sparse and thus fill areas are relatively sensitive.

Continental alluvium - Areas have slight slopes and little vegetation; visual absorption is very low.

4. Fresh water deposits

Lake beds and playas - Extremely low absorption. Nearly perfectly flat area with little tall, obstructing vegetation. General aspect is of horizontal lines. Perpendiculars will stand out.

Organic deposits - The areas are flat but usually associated with thick vegetation so that structures might be placed without great impact.

guidance SITE IMPACT/2 Site Topography
5. Marine

Coastal plains - Low rolling parallel ridges and forested land alternating with farmed land provide a pleasing combination of openness and closure. If handled well, these areas could be relatively insensitive and at the same time present opportunities for fine views.

Beach ridges - Relatively absorptive. Similar to coastal plains.

Tidal flats - Flat with little vegetation, so susceptibility to visual impact is extremely high.

6. Metamorphic

Slate - Rough topography and forested conditions make high visual absorption.

Shist - In arid regions, forms are stark and vertical, and thus of high absorption. In humid regions, forms are rounded hills with vegetative cover and high absorption.

Gneiss - Often forested with rounded topography. Provides relatively good visual absorption and pleasing views.

7. Glacial

Till - Depends on the controlling rock overridden or, in areas of thick deposits, is usually very flat with forest or grassland alternating so the visual absorption may be either moderate or low.

End moraines and ground moraines - The slightly rough topography contributes some closure and vegetation varies from area to area.

Drumlins - Convex forms expose anything built on them to the surrounding area but they are sometimes forested and the views presented may have great interest.

Eskers and kames - Esker is often forested and raised with moderate absorption. Kame is sometimes forested, often agricultural with low absorption. It too is a raised area, exposed to the surroundings.

Outwash - The land on the whole is flat and good for agriculture if drained well. Its visual absorption capability is low. Sometimes wet areas cause it to be retained as forest in which case absorption is increased. (A valley train-outwash is more enclosed and has a much higher absorption capacity.) Very gravelly outwash is much rougher and has high absorption.

guidance SITE IMPACT/2 Site Topography

Lake beds - Extremely flat areas usually with agricultural crop use so that the visual absorption ability is low.

Permafrost - Often no noise or visual absorption. Structures must be designed and coordinated well or carefully placed in a coniferous forest.

8. Igneous

Granite - Roughly rolling topography and usually forested condition give the area high absorption ability.

Basalt flows - Areas often have little vegetation. The topography varies but usually is more flat so that visual absorption ability is low.

9. Sedimentary

Sandstone - Usually smoothly rolling, massive, forested hills make absorptive ability great.

Shale - Rolling hills add to absorption ability, but they are usually used for agriculture. Still, the general effect is one of enclosure.

Limestone (arid) - Generally, the land is flat and barren, so absorption is low.

(Humid) - In resistant rock, absorption is low, as it is usually cleared and flat. Karst topography has high absorption due to enclosed topography, roughness, and often forested condition.

Interbedded - Depends on local conditions.

Coal - No comment.

d. Landform stability**1. Wind laid**

Sand dunes - Cut slopes should be kept less than 34 degrees (sand's natural angle of repose). See also "Wind erosion susceptibility" and "Clearing of natural vegetation."

Loess - Stable as long as it is kept in its natural well-drained state. Otherwise, slides and slumps are common. Cuts made above the water table should be vertical to keep the soil dry. They also should be terraced with walls nearly 90 degrees up, and flat sections should be sloped back slightly to catch the water in concrete culverts and take it away. Below the water table, a gentle slope is good as long as nothing obstructs the water flow (e.g., a nonporous retaining wall).

guidance SITE IMPACT/2 Site Topography**2. Water laid**

Flood plains - The land is stable but flooding puts down and sometimes takes away layers of earth. Because of this and the force from a flooded river, permanent structures should not be built in a flood plain. Also, see "Clearing of natural vegetation." For excavation, sheeting may be needed as retaining walls because of unstable organic deposits and a high water table.

Terraces - These are stable, excellent foundations for structures, and usually a good source of gravel.

Deltas (birdsfoot, arc, and esturine) - Not usually too stable, as they are prone to flooding. These deltas often build themselves up and outward. Also, the channels are likely to change their beds from time to time.

(Arc only) - More stable. Many were formed during glacial times and are no longer changing.

(Esturine only) - If erosion begins, it can spread greatly. See "Clearing of natural vegetation."

3. Alluvial

Alluvial fans - Land surface extremely unstable; see "Erosion by water" and "Ease of sedimentation." All development should be where water has been dispersed and slowed, no closer than two-thirds the distance away from the mountain source.

Valley fill - Still subject to periodic flash floods, but much more stable than alluvial fan.

e. Erosion susceptibility by wind**1. Wind laid**

Sand dunes - Very high susceptibility. All structures or developmental plans for a dune-beach area must take into account the shifting sand and moving dunes. Snow fencing is not highly effective and is unsightly. Various types of grasses can be planted for stabilization in little used areas.

Loess - High susceptibility. Since it was wind laid, large exposures can occur by soil movement. Therefore, try to keep it in vegetative cover when possible. The size is right for wind transport.

2. Water laid

Flood plains - Blown silts may be significant in areas of higher wind speeds, usually in northern areas (such as Alaska).

guidance SITE IMPACT/2 Site Topography

Terraces - Low susceptibility, as most of the material is coarse and too heavy to be lifted by wind. However, it is sometimes covered with a layer of loess because it is closely associated with rivers, and loess is susceptible to wind erosion.

Deltas (birdsfoot, arc, and estuarine) - Usually low susceptibility due to soil wetness.

3. Alluvial

Alluvial fans - An important process, as the surface is minimally protected or stabilized by vegetation. Strong, unobstructed winds cause saltation and sand transport with sand storms resulting.

Valley fill - Same as alluvial fans.

Continental alluvium - See "Alluvial fans, erosion susceptibility by wind." An important source of erosion is the pits, called "deflation basins," caused by active wind erosion. They may be started by poorly protected areas (e.g., those caused by cattle wallows) and may spread to become 60 feet in diameter and 6 to 8 feet deep or more. Try to plant (possibly grasses) or guard from wind (with fences or windbreaks).

4. Freshwater deposits

Lakebeds and playas - High silt content makes them susceptible; protective vegetation should be planted.

Organic deposits - Little or no susceptibility.

5. Marine

Coastal plains - Little susceptibility.

Beach ridges - Strong winds may lower some ridge tops or make wind gaps through them; these are rather slow processes, however.

Tidal flats - No comment.

6. Metamorphic

Slate - Susceptibility depends on local conditions.

Shist - Susceptibility depends on local conditions.

Gneiss - Slight susceptibility.

guidance SITE IMPACT/2 Site Topography**7. Glacial**

Till - Low susceptibility.

End/ground moraines - Slight susceptibility.

Drumlins - Slight susceptibility, as the material holds together well (i.e., it is compacted) and is often protected in a forest cover.

Eskers and kames - Little susceptibility. Materials are coarse.

Outwash - Low susceptibility except where silt deposits can still be found, but probably did suffer greatly from wind erosion during glacial times.

Lake beds - Soils usually not susceptible. Wind erosion has caused the slight undulations present, but usually low susceptibility now.

Permafrost - Little erosion due to matted sedges, grasses, or forest. If vegetation is not present, wind erosion is a distinct possibility, depending on soil type and dryness.

Basalt flows (arid) - Not very susceptible, as the decay materials are generally coarse; wind is common, however.

(Humid) - Low due to loamy soils' cohesion.

8. Sedimentary

Sandstone - Not very susceptible. The land is usually vegetated.

Shale - Low erosion, as soils are usually cohesive.

Continental alluvium - High chance of erosion. Changes to better the situation are unlikely unless the water table is low enough that previous structural soils collapse and compact under their own weight. In this case, subsidence would set in, cracking foundations and causing transportation beds to separate.

9. Freshwater deposits

Lakebeds and playas - Stable.

Organic deposits - Usually very stable if kept in a natural condition. Developments for which support is important should have foundations tied to some other underlying material that has more bearing capacity.

guidance SITE IMPACT/2 Site Topography**10. Marine**

Coastal plains - Normally stable, but layers that hold water may become too heavy and slump.

Beach ridges - Rather stable.

Tidal flats - Susceptible to water erosion.

11. Metamorphic

Slate - Due to the layered material, if a cut is made into the base of oblique-lying outcrop, the slope is susceptible to slide. If cuts must be made, make them shallow and terrace them down the slope side.

Shist - Low susceptibility. When a cut exposes fresh rock to weather moisture, the rock begins to decay and form a debris slope. Structures and retaining walls at the bottom of these slopes could be buried. Any cuts (such as for roads) should be terraced.

Gneiss - The rock is very stable, but the soil is prone to erosion. Exposed rock on steep slopes will break off and spall slowly. Most unstable areas are related to the rock fractures.

12. Glacial

Till - Slumping on any slope (particularly in the Midwest's thick till) is a real problem. Slumps often occur on river banks.

End/ground moraines - Good, steep slopes of wet fines will slump or run.

Drumlins - Stable.

Eskers and kames - Very stable.

Outwash - Stable. Gravels may need compaction. Under the water table, outwash becomes unstable and requires retaining sheeting to avoid soil flow.

Lake beds - Stable, except that where a cut is made, the weight and nature of the soils may make a bulge by weight in the bottom central portion of the cut. Giving support to cut faces can minimize this.

Permafrost - Very unstable for a number of uses. Often, putting an uninsulated heated building there melts the ice and thus causes major shiftings in the land nearby. Therefore, insulate structures by (1) using a gravel pad, (2) placing on pilings above ground and ventilating the in-between place, and (3) refrigerating foundations.

guidance SITE IMPACT/2 Site Topography**13. Igneous**

Granite - Very stable, but rock slides, loose exfoliations, and creep are common and should be investigated.

Basalt flows - Loose materials very prone to slumping. See "Bearing weight ability."

14. Sedimentary

Sandstone - Very stable.

Shale - Subject to slump, creep, or rock fall on slopes, particularly when wet. Terrace is steep or has extensive cuts.

Limestone (arid) - Very resistant, no problem.

(Humid) - Relatively low resistance; borings must be taken to prevent damage by collapse. Mitigation techniques: (1) fill with stone and concrete; (2) use grouting: pumping concrete slurry into openings (costly).

Interbedded - The main problem of interbedded formations, particularly tilted ones, is that layers have different properties, the bounds between layers are often weak, and saturation caused by heavy rains weigh down layers and put added stresses on the rock structure. A clay-limestone formation is unstable because limestone is permeable to water, and clay is not; this causes weighting and slippage along the contact boundary. Mitigation: (1) avoid cuts through overhanging layers; (2) make sure that retaining walls provide adequate drainage.

Coal - Mines may cause above-ground subsistence and, thus, problems in cracking foundations or slump hazards.

Limestone (arid) - Sand and silt-size particles can blow if not protected by vegetation.

(Humid) - Slight resistance.

Interbedded - As for the individual rock units.

Coal - Spoil piles are generally exposed without vegetation and might present a problem.

guidance SITE IMPACT/2 Site Topography

f. Bearing weight ability

1. Wind laid

Sand dunes - Very good, but foundations often are undermined and broken as wind blows away the supporting sand.

Loess - Good as long as it is kept dry. See "Landform stability."

2. Water laid

Flood plains - Varies, with a wide range of materials sorted and deposited. Care should be taken to investigate subsurface conditions, as underlying deposits of lesser strength material may cause structures to crack or fail.

Terraces - Soil is often sandy and gravelly, and therefore has very good bearing strength.

Deltas (birdsfoot) - Often large amount of plastic fines, but in complicated combinations. Thorough soil investigations must be made.

(Arc) - Coarse materials, generally good, no problem with structures.

(Estuarine) - Organic materials not good; must strip off organics and replace with good foundation materials for all structures.

3. Alluvial

Alluvial fans - Extremely high ability due to coarse texture, but needs compaction.

Valley fill - High, but more fines (silts and clays) present than in alluvial fans.

Continental alluvium - Reasonable; made up of sands, silts, and clays. See "Shrinkage-swell amounts."

4. Freshwater deposits

Lake beds and playas - Fine clays often cause problems. Also subsurface (pre-lake bed) features may change properties.

Organic deposits - Very low due to organic soils.

5. Marine

Coastal plains - Varies a great deal, but usually good.

Beach ridges - Generally granular soils, good bearings with a little compaction.

guidance SITE IMPACT/2 Site Topography

Tidal flats - Very low; use underlying strata for structure foundation.

6. Metamorphic

Slate - Poor, usually due to tilting, high water table, and layering. It is susceptible to sliding. See "Landform stability probability."

Shist - Depends on local conditions.

Gneiss - High bearing weight ability.

7. Glacial

Till - Depends on local conditions.

End/ground moraine - Usually good enough for construction. Engineering studies will suggest proper bearing system to use.

Drumlins - Usually good enough for construction.

Eskers and kames - Good.

Outwash - Very good. Materials are coarse and well sorted (by water).

Lake beds - Fair to poor. Soils tend to flow.

Permafrost - If frozen, high. If thawed, soil and bedrock properties are the determining factors. Soils and bedrock are usually poor because of organic content of reeds and sedges or forest. Further thawing may occur and shift the land (see "Landform stability probability").

8. Igneous

Granite - Extremely high.

Basalt flows - Good as long as there is no nearby cliff. Basalt is characterized by octagonal columns and should one be removed on a cliff edge, the adjoining ones take over the load.

9. Sedimentary

Sandstone - Very good.

Shale - All right.

Limestone (arid) - Soils are more coarse, possibly will not need to tie into bedrock.

guidance SITE IMPACT/2 Site Topography

(Humid) - Rock is good enough in areas hollowed by solution. Soils are poor, usually because of clays; foundation tie into bedrock is possible.

Interbedded - Generally all right in flat bedded deposits, depending on surface materials. Questionable for sloping materials, which need on-site geologic investigation. (See "Landform stability probability.")

Coal - Generally too valuable to build on.

9. Shrinkage--swell amounts

1. Wind laid

Sand dunes - Shrink and swell rates are almost the same.

Loess - Rather high, so that foundations may crack; to be avoided. If used, make sure there are no water lens at location; if so, drain them artificially.

2. Water laid

Flood plains - Shrink and swell depend on the soil types encountered.

Terraces - Little, if few impurities are present.

Deltas (birdsfoot) - High from clay content.

(Arc) - Low due to granular soils.

(Estuarine) - Organic material extremely high depending on water content.

3. Alluvial

Alluvial fans - Coarseness of most material causes minimal shrinkage-swell.

Valley fill - Not much in most except for dampened clays, in which case structure foundations must be extended below clay level to a more stable foundation.

Continental alluvium - High shrink-swell levels when wet.

4. Freshwater deposits

Lake beds and playas - Clays are often plastic and their gentle deposition by water makes the soils compactible and subject to volume changes, particularly upon addition of moisture. Structures such as roads require stable fill materials.

guidance SITE IMPACT/2 Site Topography

Organic deposits - Huge amounts of shrinkage and swelling due to the high water absorption ability.

5. Marine

Coastal plains - Generally moderate, but high for selected layers of clays and fines. Plains contain swamps and organic deposits in depressions which have large shrinkage-swell amounts.

Beach ridges - Not much as materials are coarse. They will compact slightly, however.

Tidal flats - Usually composed of organics mixed with silt, clay, and sometimes sand. As such, have high shrinkage-swell.

6. Metamorphic

Slate - Range of particle sizes from gravel to clay makes changes minimal.

Shist - Depends on local conditions.

Gneist - No comment.

7. Glacial

Till - Depends on local conditions.

End/ground moraines - Depends on local conditions.

Drumlins - No comment.

Eskers and kames - Low.

Outwash - Low because of coarseness.

Lake beds - High due to sorted nature of materials and their mixing in movement.

Permafrost - Extreme because of soil's high water content and volume change upon freezing and thawing. Primary reasons for slides and slumps.

8. Igneous

Granite - Not usually a problem

Basalt flows - In volcanic shield, clays from ash cause cracking and creep. Shrinkage-swell is great upon water addition because bentonite sheet structure accepts water easily (high montmorillonite content).

guidance SITE IMPACT/2 Site Topography

(Arid) - Can be compacted.

(Humid) - Moderate.

9. Sedimentary

Sandstone - Low, although the sand can be compacted slightly.

Shale - In regions with a wet/dry seasonal change and in soils with a large percentage (over 35 percent) of montmorillonite clay, shrink-swell may be great.

h. Frost heave potential**1. Wind laid**

Sand dunes - Little potential, as it is well drained unless (1) another less permeable substance is near the surface which will store water and, thus, expand when frozen, and (2) water table is very near the surface.

Loess - High; see "Shrinkage-swell amounts."

2. Water laid

Flood plains - Very high, as freezing and thawing of the high water tables often crack foundations and structures.

Terraces - Low, unless there are local lens of finer materials such as clay.

Deltas - (birdsfoot, arc, and estuarine) - Extreme, due to potential freezing of high water table.

(Arc only) - Much less of a problem due to coarseness of soils.

3. Alluvial

Alluvial fans - Little; generally dry and often warm.

Valley fill - Little; generally dry and often warm.

Continental alluvium - Although the soils are right for frost heave, the wet and cold seasons are not coordinated so the potential is low.

4. Freshwater deposits

Lake beds and playas - Most are warm but where freezing does occur, heave is problem. The clays are subject to volume change and hold water well.

guidance SITE IMPACT/2 Site Topography

Organic deposits - Only reasonably high, in spite of the high water table. The organic matter is good insulation in winter and will not freeze unless tundra predominates in the area.

5. Marine

Coastal plains - Reasonably high potential as the plains are formed by soil layering with some acting as water storage layers. If these are close to the surface, they may heave in cold weather.

Beach ridges - Low potential; soils are well drained.

Tidal flats - High potential.

6. Metamorphic

Slate - Low potential, as the soils drain water well due to cracks in their structure.

Shist - Some problems due to semipermeable hardpan in B-horizon; also seepage can cause foundation failure.

Gneiss - Very high potential, as the temporary rock or hardpan perched water table is susceptible to spring freezing.

7. Glacial

Till - Poor internal drainage in regularly freezing areas results in frost heave.

End/ground moraines - Seasonable high water table contributes to a rather high frost heave potential.

Drumlins - Low potential, as they are well drained.

Eskers and kames - Low potential, as they are well drained.

Outwash - Low potential, as the soils are coarse and well drained.

Lake beds - High water table and plastic soils cause high potential.

Permafrost - A common problem. Surface freezing-thawing causes significant bumping of the land surface.

8. Igneous

Granite - High potential, as there are pockets of water on bedrock near the surface.

guidance SITE IMPACT/2 Site Topography

Basalt flows (arid) - Low; dryness and coarse materials usually drain well.

(Humid) - Frost heave possible due to high water table and loamy soils, particularly if frost reaches the hardpan B-horizon.

9. Sedimentary

Sandstone - Low potential because of dry, well-drained soils.

Shale - Great; as the shallow, wet soils freeze often, most structures will need a coarser fill for base grade.

Limestone (humid) - High. Although water table is usually 10 to 12 feet below the surface in well-drained soils, the soil clumps themselves hold water while the soil is drained by the interclump cracks.

Interbedded - Depends on local conditions.

Coal - Depends on spoil materials. Usually low if spoil consists of well-drained parent material.

Limestone - In regions with a wet/dry seasonal change and in soils with large percentage (over 35 percent) of montmorillonite clay, frost heave may be great.

Interbedded - In regions with a wet/dry seasonal change and in soils with a large percentage (over 35 percent) of montmorillonite clay, frost heave may be great.

Coal - Not applicable.

I. Site modifications

1. Grading

Disposal - Unsatisfactory or satisfactory material shall be disposed on the base or post on which a project is sited and in a location and way as directed by the Post Engineer.

Stockpiling - Satisfactory materials suitable for backfilling and embankment construction shall be conveniently stockpiled in proximity to the proposed work in a location and way as directed by the Base Civil Engineer.

Site grading must provide drainage away from all structures, walks, antennas and their foundations, and other antenna-associated equipment. The grading design must also control erosion and any areas of standing water.

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For finished grading, a slope of no less than 2 percent for turfed areas is desirable; however, more permeable soils, such as sandy types, may require less slope. Drainage slopes away from buildings shall be a minimum of 6 inches vertical for a horizontal distance of 10 feet. Banks for transitions from one area to another shall not be steeper than 1 foot vertical in 3 feet horizontal. Steeper slopes may be used with rock outcrops of vegetation cover, other than turf, which can be established and maintained easily.

Runoff water shall not be permitted to pond over or adjacent to the proposed structure.

Turf shall be placed in all designated areas within the grading limits.

Grading design shall take into consideration the following criteria: (93) 4-4

- a. Development of economic building sites.
- b. Disposal of surface water.
- c. Preservation of the natural character of the terrain by minimum disturbance of existing ground forms and vegetation cover, except when disturbance is necessary for facility mission.
- d. Minimum earth moving with reasonable balance of cut-and-fill.
- e. Avoidance of earth banks entailing costly measures for erosion control.
- f. A minimum number of steps to entrance.
- g. Establishment of satisfactory grade levels around buildings.

3. a. Soils/bedrock

Geological data should be collected and analyzed for the areas being considered for facility sites. The analysis should consider earthquake frequency and severity, location of faults, results of test borings, and general soil stability. (2) 4-49

Adverse geological conditions shall be a reason for rejecting a potential site. The nature of the terrain, surface and subsurface, as well as local seismic conditions shall be considered thoroughly to assess the degree to which site components and functions may partially or totally degrade. (9) 5.1.3

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The amount of subsurface soil information required is limited by the amount of effort the survey team is directed to spend. Information should include, but is not necessarily limited to, (1) soil bearing data and access to places where antenna supports may be located, (2) soil conductivity, and (3) locations of buried construction, such as utilities, that might interfere with routings of buried coaxial cable, technical power, and antenna supports. At existing bases, subsurface soil data may be available from existing borings or foundation excavations in the areas near the proposed new location. At undeveloped areas, surface observations may suffice; if time permits, however, subsurface information should be obtained by digging test pits for visual observation and by taking penetrometer readings of the bearing capacity at each change in strata. Test hole locations are to be recorded on the site topographic drawing. The penetrometer readings and visual observations are to be recorded on soil data sheets. Soil samples should be taken from the test pits and kept in jars. These samples must be properly identified, recorded, and submitted with a site report. The depth of ground water table and seismic data shall be obtained when possible. (31) 2-9

Poor soil conditions should be avoided if possible. Although with present soil analysis methods and foundation design knowledge almost any type of soil condition can be overcome, this may be at a considerable increase in construction costs. (31) 2-12

b. Conductivity

Soil resistivity should be measured at several points over the area of the planned facility. The area to be examined depends on the actual size of the facility. For large facilities, the area is assumed to extend at least 6 meters (20 feet) beyond the basic structural outline. Refer to SB6 "Grounding, Bonding, And Shielding" for detailed information.

c. Vegetation

Vegetation shall not interfere with antennas and ground mats. Some site areas must be kept free of vegetation; the designer shall consult electronic system engineers for this information. (92) 12.1-11 See Volume 1A, "DCS Transmission Facilities," for information on specific antenna systems. See also NAVFAC DM-5.11 and DM-13 for other landscaping and ground cover guidance except for the following: (92) 12.1-11

1. Planting of trees, shrubs, and ground cover for aesthetics will be included as an integral part of the design and funding of a project in the degree appropriate to each type of facility. Landscape planting plans should be developed by a qualified landscape architect on the basis of the approved plan for the installation.
2. When buildings are combustible, fire breaks shall be provided in accordance with NAVFAC DM-8 or equal. Fire break

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requirements within the antenna field shall be based on the specific exposure hazards.

See also SB7--"Security Systems" for allowable vegetation in regard to specific perimeter security devices.

d. Clearing of natural vegetation**1. Wind laid**

Sand dunes - Extremely high impact. Although vegetation may be sparse, it is the major deterrent to wind erosion. Therefore, great care must be taken to disturb as little as possible, particularly in the area between the shore and first ridge line.

Loess - Relatively little impact except if it is completely cleared; it is exposed to problems listed under "Erosion susceptibility by wind and water."

2. Water laid

Flood plains - Clearing was a definite effect, as it allows water to move through faster to avoid flooding in an area. This is standard flood control practice. However, clearing causes the water to reach a downstream point sooner, with the same amount passing through in less time; therefore, greater volume reaches the downstream point. Effects are additive and require downstream flood control which produces a vicious circle, causing more and more damaging floods. Therefore, avoid complete clearing when possible. Instead, leave at least a fence of trees to act as a barrier.

Terraces - Often have steep, unstable slopes and cliffs. Vegetation removal makes terraces more unstable.

Deltas (birdsfoot, arc, and estuarine) - Stability of these landforms depends on water flow control by vegetation. Clearing has very high impact.

(Birdsfoot) - Trees and bushes slow water, channelize it, and promote sedimentation and land building. Do not clear in a way that will form a new channel.

(Arc) - More stable due to coarseness of soils. Good as a marine site.

(Estuarine) - Vegetation builds the land; if it is removed, erosion pockets may form or banks may become unstable and begin to be undercut.

3. Alluvial

Alluvial fans - There is little to clear in these usually dry areas. However, the shrubs interfere slightly with

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saltation by wind and, thus, aid in preventing wind erosion. See "Erosion by wind." Vegetation most commonly grows along the gully bottoms, using and directing water flow.

Valley fill - Same as for alluvial fans.

Continental alluvium - Same as for alluvial fans.

4. Freshwater deposits

Lake beds and playas - Vegetation slows and captures windblown material. See "Erosion by wind."

Organic deposits - See "Groundwater pollution."

5. Marine

Coastal plains - Clearing has no great impact.

Beach ridges - Stabilized by vegetation; removal can initiate massive wind erosion.

Tidal flats - See "Delta, estuarine."

6. Metamorphic

Slate - Vegetation removal will expose soil to increased water erosion. In arid regions, the effects of erosion increase greatly.

Shist - Vegetation removal will expose soil to increased water erosion. In arid regions, the effects of erosion increase greatly.

Gneiss - Clearing will cause erosion, particularly on the steeper slopes, because of increased runoff.

7. Glacial

Till - In grasslands, the impact of clearing is considerable. The grasses' root system holds the soils together tightly; thus, these soils are vulnerable when cleared.

End/ground moraines - Clearing causes no more than normal exposure of soil to weather.

Drumlins - Clearing has little impact.

Eskers and kames - Not usually a problem.

Outwash - Not usually a problem.

Lake beds - Soil types make the area susceptible to sheet erosion and silting in rivers and ponds. This can be

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minimized by keeping vegetation (forest) along the drainageways to catch the material before it reaches the stream.

Permafrost - Vegetation creates a stable balance in the energy exchange; clearing changes the equilibrium and may cause thawing that leads to erosion. Therefore, if you clear, reestablish the balance by using suitable materials with the same properties, insulation, or mechanical temperature-control devices.

8. Igneous

Granite - Clearing will expose shallow soils to water and wind and decrease their matted character.

Basalt flows (arid) - Little impact.

(Humid) - Normal impact.

9. Sedimentary

Sandstone - Clearing is not usually a problem.

Shale - High impact; clearing exposes the soil to unchecked sheet erosion and greatly increased storm discharge (see "Erosion susceptibility by water").

Limestone - Clearing is not usually a problem. Care should be taken along lake and river banks, however. Effects of erosion and chemical dissolution are worsened in humid regions.

Interbedded - Depends on local conditions. Vegetation often preferentially grows on one layer in the beds; removing that layer's vegetation can affect adjoining layers.

Coal - No unusual problems from clearing.

e. Dust generation**1. Wind laid**

Sand dunes - No dust, although blowing sand is often a problem and will wear away construction equipment parts rather quickly.

Loess - If cleared and exposed, dust is a great problem. Try to keep loess covered with something, particularly at windy sites.

2. Water laid

Flood plains - In areas of silt deposits or general high winds, dust is very important to consider.

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Terraces - Low, unless uncovered with loess; see "Erosion by wind."

Deltas (birdsfoot, arc, and estuarine) - Usually low dust levels due to soil wetness.

3. Alluvium

Alluvial fans - Sandstorms common. Sand that gets into mechanical parts increases wear.

Valley fill - Because of the higher proportion of silts compared to alluvial fans and the water-sorted landform character, it is susceptible to dust as well as sand generation. These materials increase wear of mechanical parts when they make contact.

Continental alluvium - High dust generation. See "Valley fill."

4. Freshwater deposits

Lake beds and playas - Silt and dryness cause high susceptibility. Try not to leave unvegetated areas.

Organic deposits - No dust.

5. Marine

Coastal plains - No comment.

Beach ridges - Some blowing sand.

Tidal flats - Dust is not usually a problem.

6. Metamorphic

Slate - Not usually a problem.

Shist - Not usually a problem.

Gneiss - Not usually a problem.

7. Glacial

Till - Dust depends on local conditions. Loess deposits often are formed by the silt from till.

End/ground moraines - No comment.

Drumlins - Though drumlins consist of the right size materials for dust generation, the compressed landform makes it less of a problem.

Eskers and kames - Low dust generation.

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Outwash - Low; the particles are too coarse.

Lake beds - Some dust, as the area is flat, has no major obstructions, and contains relatively large amounts of silt.

Permafrost - Low; the soil's high moisture and organic contents are not conducive to dust generation.

8. Igneous

Granite - Dust is possible if granite is exposed because it is generally dry and has coarse soil texture.

Basalt flows (arid) - Low, due to coarse materials.

(Humid) - Moderate.

9. Sedimentary

Sandstone - Low dust generation.

Shale - Low; soils are cohesive.

Limestone (arid) - Sand and silt blowing are likely.

Coal - No comment.

f. Ease of utility layout

Local power supply must be investigated to determine availability, adequacy, or modifications necessary to make it suitable. The information obtained should include personal observations (actual measurements) plus the results of questioning local personnel, power company representatives, and any other cognizant agencies or power users in the site area. If possible, obtain a one-line diagram of the system that furnishes power to the proposed site. This should include distances, wire sizes, voltages, frequency, phases, switching stations and locations, and capacities of transformer banks of all consumers between the nearest substation and the proposed site. If a one-line diagram is not available, it should be prepared from the information obtainable from the power company and submitted as part of the Site Survey Report. If answers to the above questions are not readily obtainable at the time of the visit to the power company, it is suggested that a copy of all unanswered questions be left with the power company, with the urgent request to have questions answered by mail as quickly as possible to the cognizant DCEO office. If possible, visit one or more of the commercial power subscribers in the vicinity of the proposed site to ascertain their experiences with the power as to reliability, frequency and duration of "outages," fulfillment of demand requirements, and voltage and frequency variations. The type of equipment used by the subscribers should be noted, since it will affect their sensitivity to power supply irregularities. (31), 2-9

guidance SITE IMPACT/3 Site Characteristics

1. Wind laid

Sand dunes (electric/gas) - Easy to excavate and lay out lines.

(Storm/sanitary water) - Poorly developed drainage pattern may cause difficulty in gravity-dependent system, necessitating lift pumps.

(General) - The walls may slump in as you reach the water table. A remedy is to stabilize with a temporary retaining structure.

Possible high metal corrosion results if saltwater is near or under the freshwater table.

Loess (electric/gas, storm/sanitary water) - Generally very easy to lay out. Some problems result if you must cross a ravine, as the slope banks are often very steep.

2. Water laid

Flood plains (storm/sanitary water) - Flatness may make layout of gravity controlled systems difficult. High water table often gives sanitary systems with breaks or leaks a high pollution potential.

(General) - Usually very flat, but often has pockets of wetland around which systems must be built.

Terraces - No great problems. Material is easily removed for excavation.

Deltas (electric/gas, storm/sanitary water) - High water table will cause problems.

(Electric only) - Corrosion potential high on buried utility lines for estuarine areas.

3. Alluvium

Alluvial fans (electric/gas, storm/sanitary water) - Layout relatively easy and low cost due to granular soil and ease of movement. Large boulders should be avoided and lines should be placed well below the level of possible stream-bed erosion from a flash flood.

Valley fill (electric/gas, storm/sanitary water) - Layout relatively easy and low-cost due to granular soil and ease of movement; avoid large boulders and ravines.

Continental alluvium (gas, storm/sanitary water) - Layout relatively easy with normal costs; trench sides sometimes cave in, so you might need sheeting. Also, salt can corrode metal pipes.

guidance SITE IMPACT/3 Site Characteristics

4. Freshwater deposits

Lake beds and playas (electric/gas, storm/sanitary water) - Very flat, easily laid out; a problem could result from a high water table. In dry regions, salt and other minerals may have a high corrosion potential.

Organic deposits (electric/gas, storm/sanitary water) - A high water table makes layout difficult. Soil acidity also may cause significant corrosion.

(Storm/sanitary water only) - Flatness will cause some difficulty.

5. Marine

Beach ridges (electric/gas, storm/sanitary water) - Layout may be difficult across ridges that are parallel to each other. Excavation is cheap in granular material (sand and gravel) when the water table is low.

Tidal flats (electric/gas, storm/sanitary water) - Flat surfaces mean rather easy layout. A high water table can make layout difficult, however. A high corrosion potential is possible from saltwater. In excavation, materials below the water table will flow, so sheeting will be needed for retention.

6. Metamorphic

Slate (electric/gas, storm/sanitary water) - Problems occur with rough topography and bedrock near the surface (soil is usually less than 4 feet deep).

Shists (electric/gas, storm/sanitary water) - Layout is not too difficult for rock. The landforms are somewhat rounded and if the soils are not deep, rock can be ripped out for excavation.

Gneiss (electric/gas, storm/sanitary water) - Gneiss has rounded landforms of very resistant rock, often exposed. As a result, there are major problems because the shallow bedrock interferes with direct layout and adds to cost.

(Storm/sanitary water) - It may be difficult to route gravity systems around the nearly exposed material, yet keep it below the frozen ground level.

7. Glacial

Till (electric/gas, storm/sanitary water) - Rather flat, making layout relatively easy.

End/ground moraines (electric/gas, storm/sanitary water) - Some problems with an occasional high water table.

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particularly in the Midwest (as opposed to the coarser eastern soils).

(Storm/sanitary water) - Layout becomes difficult for gravity systems because the topography is rolling and deranged.

Drumlins (electric/gas, storm/sanitary water) - Uncomplicated form makes layout relatively easy, but material is compact so that excavation costs for trenching are higher than would be expected.

Eskers and kames (electric/gas, storm/sanitary water) - Layout is difficult. These areas have a steep small form, but are well drained because of the coarse materials present.

Outwash (electric/gas, storm/sanitary water) - Layout is relatively easy, as the topography is flat or slightly rolling. Some layers may carry water, so a high aquifer may cause problems. See "Landform stability probability."

Lake beds (electric/gas, storm/sanitary water) - Always extremely flat, making layout easy. A high water table often will cause problems.

Permafrost (electric/gas, storm/sanitary water) - Layout is difficult; use insulated tubing and piping in conduits to preserve temperature balance. Also, high cost is associated with excavation, so consider placing above ground and insulating.

8. Igneous

Granite (electric/gas, storm/sanitary water) - Rolling topography, shallow (and hard) bedrock, and seasonal high water table make layout difficult.

Basalt flows (electric/gas, storm/sanitary water) - Depends on topography, but rock is usually near the surface and makes layout difficult and costly. Loose materials will need stabilizing with sheet piling.

9. Sedimentary

Sandstone (electric/gas, storm/sanitary water) - Rolling topography and shallow soils cause some problems. Costs increase greatly when rock is encountered in excavation, when heavy equipment or blasting must be used.

Shale (electric/gas, storm/sanitary water) - Soils are sticky and cohesive and depth to bedrock is not great, although the rock can be ripped easily. A high water table and rolling topography make layout difficult.

(Storm/sanitary water) - All of the above apply, particularly to the gravity systems.

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Limestone (electric/gas, storm/sanitary water; arid) - Usually flat, resistant table rocks make layout easy but cost is high if one must excavate in rock.

(Electric/gas, storm/sanitary water; humid) - Karst and tropical karst topography make layout difficult.

(Storm/sanitary water) - Layout is very difficult for gravity systems as there is much negative drainage; it is likely that pumping stations will be necessary.

Interbedded (electric) - Quick changes between layers (such as limestone-clay) set up an electrical charge that corrodes metals. It may be cheaper to go the longer route and stay within one formation.

Coal - No comment.

4.a. Access for logistic support

The procurement, distribution, maintenance, and replacement of material and personnel during construction/installation and O&M phases of the station's life cycle are important considerations in the system design and engineering process.

Sites should be compared relative to the costs of transporting fuel, personnel, water, and other supplies. If the only access to a site is by aircraft or aerial tramway, development and operation costs are usually prohibitive. (2), 4-49

1. Roads

All roads and vehicle parking areas with grades equal to or less than 12 percent (refer to TM 5-822-2, Table 1) shall have an asphaltic concrete surface course. For vehicular pavement areas steeper than 12 percent, P.C.C. shall be used. The pavement sections shall be designated by FED.

The condition of existing access roads and highways leading to the site should be known. Other conditions, such as slope, constructions, curves, bridges, culverts, drainage, surfacing, turnouts, weather effects, and weight limitations on bridges and roads, all are important considerations in determining site suitability. (31) 2-8

When access roads to the site do not exist, a survey team should prepare a map or plan showing the site in relation to existing roads, suggested routing, contours, vegetation, and surface and subsurface soil conditions. Final routing of any new access road can be made during the site survey or at a later date, depending on available time and other conditions. (31) 2-8

Easements are very often all that is needed to obtain access to the site, so the actual purchase of land for an access road may not be necessary. For the use of existing

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roads, leases or agreements may have to be entered into with the governing agency or owner. (31) 2-8

Before the development of all-weather site access roads and parking areas, a preliminary engineering study should take into account vehicular traffic demands. Although the final access road position will depend primarily on site location, layout, and topography, the final design should offer direct routing, adequate right-of-way visibility, good foundation, proper drainage, and degrees of curvature and grade consistent with good highway engineering practices. (2) 5-12

The number of roads leading to a site should be minimized and their use restricted whenever possible. Control gates/barriers will limit access and speed bumps may discourage sightseers. Such measures probably will require coordination with local authorities. (10) 6-102

All access roads shall be lined continuously by vehicle barriers from the nearest adjacent road to the site perimeter fence gate as specified in SB7--"Security Systems." Vehicle barriers shall not be used alongside an access road if the terrain immediately adjacent to the road precludes the use of four-wheel drive vehicles to avoid the road. Vehicle barriers shall not be used to line the access road at facilities where the site perimeter is less than 20 feet from an adjacent road or where the surrounding terrain offers alternative approaches to the site for four-wheel drive vehicles. Vehicle barriers shall be placed to prevent straight-line approaches by vehicles to the perimeter fence or perimeter fence gate and such such that authorized access to a site by emergency or maintenance vehicles is still available.

Access roads and bridges from the equipment delivery origin to each site shall be suitable for passage of loaded trucks with maximum weight 40,000 pounds, maximum width 10 feet, and maximum height 12 feet, 6 inches. Pavement around structures shall be sloped to provide drainage away from them.

When curbs or combination curbs and gutters are required, curbs will generally be of Portland cement concrete, reinforced or plain, as indicated by the particular job. Corps of Engineers Guide Specification 806.02 and Drawing No. 40-17-02 provide excellent guidance for curb design. Provide low, sloping curbs where vehicles access may be required for off-road use.

Curbs and gutters constructed along streets and around vehicle parking in built-up areas at all permanent installations generally will be of Portland cement concrete. They will not be constructed along roads in nonbuilt-up areas except as required to control drainage and erosion.

Curbs and gutters will not be constructed at temporary installations, except as required to control drainage and erosion or as extensions to similar existing facilities.

guidance SITE IMPACT/4 Site Circulation**2. Parking and servicing site vehicles**

Military vehicles should be secured inside the perimeter fence but should not obstruct the view of the perimeter. (10) 6-102

A paved parking area should be provided near the Technical Building, except when security measures dictate a removed parking area. The total parking area required depends on requirements at the individual site.

Guardrails, guideposts, and other safety features shall be provided in AFM 98-7, Chapter 5.

Parking stalls shall be 9 feet on-center and striped, conforming with TM 5-822-3.

All parking areas shall have concrete curbs.

Vehicle service aprons shall be large enough to permit vehicles to turn around and back up to the loading dock. The parked vehicle shall not block the traffic lanes. When designing the vehicular service aprons, street intersections, and street horizontal curves, provisions for elements such as vehicle length and radius of front wheels, rear wheels, and overhang shall conform to AASHTO, "A Policy on Design of Urban Highways and Arterial Streets."

Pavement design shall be based on the maximum loads anticipated for each individual area, but in no case shall pavements be designed for less than a 4000-pound wheel load and 40 pounds per square inch tire pressure.

Parking areas should have flexible pavements consisting of a suitably wearing surface on a stable base. Portland cement concrete pavement shall be used only when site conditions make flexible pavement impractical, or when the availability of local materials render its use more economical.

Parking lots for organizational vehicles must be approached as individual design problems. Parking for cars and light trucks should be similar to nonorganizational parking. Heavy trucks, tanks, and other specialized vehicles will require special design.

Further references for vehicular and pedestrian pavements are: TM 5-822-2/NAVFAC DM-5.5/AFM 88-7, Chapter 5; TM 5-822-5/AFM 88-7, Chapter 3; TM 5-822-6/AFM 88-7, Chapter 1; NAVFAC DM-5.4.

3. Hardstands at vehicle wash racks, etc.

No information available.

guidance SITE IMPACT/4 Site Circulation**b. Personnel walkways**

Shoulders a minimum of 4 feet wide shall be provided at the pavement edges of all road and parking areas. Sidewalks shall be of concrete and shall be a minimum of 4 inches thick.

Sidewalks shall be 4 feet wide except when the designed pedestrian traffic volume requires a wider width. Sidewalks shall be sloped to drain away from the buildings.

The maximum rise between landings of sidewalk steps shall not exceed 4 feet. Steps with less than three risers shall not be used. The proportions of handrail height, riser, tread, and other elements shall conform to EM 385-1-1.

Install inserts in pavements placed over buried metallic facilities, such as metallic pipelines, metallic sheath cables, and tanks, for proper O&M of a cathodic protection system. Electrical measurements must be made periodically on buried metallic facilities. For accurate measurements, pavement inserts must be installed at prescribed points over the metallic objects to permit insertion of a reference electrode 5-3/4 inches long and 3/8 inch in diameter. A pavement insert consists of a drilled hole, 1-5/8-inches diameter, that passes through the pavement and into the subgrade. The hole is filled with sand to within 4 inches of the top of the pavement. The hole is sealed by a removable, cadmium-plated, 3/4-inch plug fitted into a plastic insert 5 inches long. The plastic insert is hammered home flush with the pavement; sealing should be unnecessary. Pavement inserts must be installed at points where metallic facilities cross and at points spaced not more than 100 feet apart along the length of metallic pipes and cables.

Provide space at door accesses to the building for sand bag bunkers.

c. POV parking

Vehicle parking at manned DCS facilities shall be located more than 30 feet (= 10 meters) outside the site perimeter fence. Vehicle barriers shall be placed around parking lots to prevent vehicular access to the perimeter fence. No vehicles shall be permitted within the site perimeter fence except those authorized for supply and maintenance. No civilian vehicles shall be permitted within the site perimeter fence.

d. Perimeter control

See SB7--"Security Systems."

guidance WATER SUPPLY IMPACT/1 Quantities**1.a. DCS facility size and manning strength**

Whether the facility is to be installed on an existing base or on a new, independent site, provision must be made for a potable water supply for both drinking and sanitary use. Additionally, a water supply suitable for air-conditioning, humidifier make-up, general housekeeping, and fire protection shall be provided. (1) 24

When existing systems can supply actual demands plus the expansion proposed without inclusion of a capacity factor, no additional facilities will be provided except the necessary extension of water mains. In designing extensions, consideration will be given to planned future development in adjoining areas so that mains will be sized properly to serve future areas. When existing facilities cannot supply actual total requirements and new construction is necessary, the capacity factor will be applied to the proposed total population and the expanded facilities will be planned accordingly. (106) 7

Present design procedures for installations entail the use of per capita demand and capacity factors. This results in overdesign in many cases or the corresponding underuse of resources.

1. Analysis of needs

The total daily water supply requirement is obtained by multiplying the design population by per capita domestic water allowances and adding to this quantity any special industrial, HVAC, CBR, irrigation, vehicle-wash, or other demands, including the amount necessary to replenish, in 48 hours, the storage required for fire protection and normal operation. When the supply is from wells, the quantity available in 48 hours of continuous operation will be used to calculate the total supply available for replenishing storage and maintaining fire, domestic, and industrial demands that cannot be curtailed. (106) 4

2. Amounts of water required

DCS sites have few industrial or other uses (a few vehicles to wash and cooling system requirements for equipment and personnel), leaving consumption and fire demand as primary concerns. However, until the water supply factors are changed, the following excerpts from TM 5-813-1 apply. (106)

"Fire flow" is the amount of water in gallons per minute required at a specific residual pressure at the site of the fire for a specific time period. The fire demand is determined by the sum of the fire flow, 50 percent of the

guidance WATER SUPPLY IMPACT/1 Quantities

average domestic demand rate, and any industrial or other demand that cannot be reduced during a fire period. Residual pressure is specified for either the fire flow or essential industrial demand, whichever is higher. Fire demand will include quantities required for automatic sprinkler operation, in addition to direct hydrant fire-flow demand as appropriate, when sprinklers are served directly by the water-supply system. (106) 4 (See SB3--"Fire Protection/Life Safety" for further information.)

For permanent construction, the domestic water allowance is 150 gallons per capita per day for residents. The applicable capacity factor is 1.5 for small installations. Peak domestic demand is defined as 2.5 x daily average requirement. It should be noted that the 150-gallon figure includes water for laundries, vehicle washing, limited irrigation and similar uses. Often, these needs apply only when barracks are on the installation. (106) 4,5,6

Requirements for domestic and fire flow systems must be analyzed to determine whether the capacities are fixed by the domestic requirements, by the fire demands, or by a combination of both. When fire-flow demands are relatively high or are required for long durations, and population and related domestic and/or industrial demands are relatively low, the total required capacity will be determined by the prevailing fire demand. In exceptional cases, this may warrant consideration of water systems for fire safety, partly or wholly separate from normal potable water systems. However, separate systems should be avoided if at all feasible. (106) 6

For sites with shift workers, the proper design value is 50 gallons per capita per shift. (106) 5 These values can still be considered high. For example, a DEW line study with conventional water use and no restrictions had a consumptive use of 55 gallons per capita per day.

Quantity standards cannot be followed rigorously in cold regions. Water sources are limited, production costs high, and water conservation is a vital part of the design. Naval guidance for polar stations uses consumption figures of 30 to 40 gallons per capita daily when flush toilets and normal bathing and laundry facilities are provided. When flush toilets are not provided, 10 to 20 gallons per capita per day should be allowed. (109) 9-9-2 Such low levels show how little water is needed for minimum functioning if supply is a problem in locating a DCS site.

b. System survival

Correct construction practices must be followed to avoid compromising the system. (See also SB7--"Security Systems" and SB8--"Survivability Protection.")

guidance WATER SUPPLY IMPACT/1 Quantities**1. Protection of the utility system**

Utilities such as water should be accessible for maintenance either from outside the operations building or from an unclassified area. (43) 3-15

Utility openings, covers, sewers, culverts, tunnels, and other subsurface routes that penetrate the fenceline should be protected. They can provide intruders with attractive passageways with no significant delay. These openings should be eliminated or delay times increased greatly. (37) 97

Conventional grills, gratings, locked manhole covers, and other devices are some help but generally will not stop a determined intruder. The lock-on device is usually the weakest link.

Actual entry ports from tunnels or sewers to the structure should, if possible, be constructed to make their expansion into passable openings very difficult and time consuming. When fluid flow capacity is a limiting factor, multiple small openings or a larger opening filled with 4- to 6-foot (1200- to 1800-millimeters) or longer lengths of steel pipe, welded together or anchored in place securely by a welded structure on the inside, can be used. If possible, such a barrier should be located with a sharp adjacent turn in the tunnel to further restrict use of cutting tools. (37) 103

Utility connections (water and sewer) will usually be to base systems for normal operations. Such connections should include flexible features to allow for differential movements between facilities and surrounding soils.

Utility lines should be underground whenever possible, minimally 3 feet and more when weather dictates. No overhead markings should indicate their presence.

2. Reserve supply

An underground emergency water supply tank should be placed at least 10 feet (3.05 meters) within the essential facility fenceline. This tank is to be lockable. Controls on the water distribution system are to be such that this supply is not depleted under normal conditions. However, emergency water must be integral with the normal system water flow to periodically replace stored water with fresh water. Controls should then be added to enable use of this water reserve under emergency conditions. Unless more stringent criteria exist, storage capacity should be 20 gallons (75.6 liters) per capita per day for 7 days. User population should include the total DCS station complement during an emergency situation. This supply must be able to be isolated from other water supply sources. The requirement for a separate emergency water

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storage tank can be deleted if the existing supply proves adequate at all times and can be protected economically. (11) para. 4

When chemical-biological-radiological (CBR) contaminants must be considered, the decontamination supply quantities must meet the needs of the facility. A typical system using showers at 4 gallons per minute at the capability of 3 hours per day for 12 days results in 8600 gallons for showers. For more information see S88 - "Survivability Systems."

Only groundwater should be used, as opposed to surface water, during a CBR mode. Boiling and reverse osmosis treatments of surface water cannot be considered effective.

3. Alternative sources

Whenever possible, utilities are connected with local supply sources for cost-effectiveness. Development of local supplies is the next best procedure for water; trucking-in is the least desirable and should be avoided whenever possible.

4. Alternative pumping and power equipment

Redundant equipment able to use ancillary utilities should be provided.

2. a. Storage capabilities and storage tank options (110) (96)

Required daily demand = effective population x capacity factor x per capita allowance.

For example, to calculate the required daily demand for a facility with 25 people:

demand = 25 x 1.5 x 150 gallons per capita per day

demand = 5625 gallons per day.

Firefighting flow = 500 gallons per minute x 2 hours
= 60,000 gallons.

Peak domestic demand

Three methods for determining minimal storage are:

1. Use 50 percent of total daily domestic demand.
2. Use the fire demand minus production of one well under emergency conditions.
3. 1 + 2 - (production of one well in 24 hours).

Use the largest value for storage. In many areas, it is

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considered worth the extra cost of storage to insure an adequate water supply.

Storage tanks should be designed with flow-through circulation and compartments. Water storage is desirable to permit the most economical pipe sizes, provide uniform pressure, supply fire demands, and make it possible to operate the water production facilities at an average rate rather than a varying rate.

Storage tank types include ground, elevated, underground, and hydropneumatic. DCS sites would generally find underground tanks the most desirable for the following reasons: construction may be more economical, freezing protection is provided, the above ground area can be used for other purposes, and protection is provided from sabotage and destruction. In-building locations are also desirable. Other types of tanks may be suited to specific sites. Some installations may not be able to provide underground storage, such as those situated on rock outcroppings or in cold regions where permafrost precludes such construction. Buried tanks should be at least 10 feet inside the facility fenceline and isolated from other water supplies.

For onsite sources where the fire demand is stored separately or can be neglected, water tanks can be sized smaller.

Elevated tanks can be used at DCS sites if they do not interfere with the installation's primary mission. Storage tank construction can be of a variety of materials, as the following table suggests.

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STORAGE TANK MATERIALS (96) 76

	Type of Tank	Maximum capacity (gal)	Advantages	Disadvantages
Concrete	Ground storage tank Standpipes	Unlimited 1,000,000	Large volume. Lower maintenance cost than steel. Adaptability to architectural treatment. Ease in burying underground.	Low head; do not exceed 50 feet. Greater weight. Higher first cost than steel. Less watertight, unless prestressed.
	Underground storage tanks	Unlimited		
Steel	Elevated storage tanks	5,000,000	Adaptability to high heads.	Higher maintenance and protection costs than concrete. Require protection against freezing. High cost per unit stored.
	Ground storage tanks	10,000,000	Ease of erection.	
	Hydropneumatic tanks	15,000	Lower first cost than concrete. Stores water under pressure.	
	Standpipes	1,000,000	Lighter weight than concrete. Leaks easily repaired.	
Wood	Elevated storage tanks	100,000	Low cost.	Not watertight. Small volume. Short life.
	Ground storage tanks	100,000	Ease of erection.	
Fabric	Ground storage	20,000	Low cost. Ease of erection. Portable.	Not watertight. Small volume. Short life.

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Design criteria specifications and appurtenances are in TM 5-813-4 and NAVFAC DM-5.7. The desired water line pressure is 40 pounds per square inch.

Special construction procedures and considerations may be required for cold regions, including thermal insulation. The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Special Report, "On-Site Utility Services for Remote Military Facilities in the Cold Regions" and the U.S. Environmental Protection Agency (USEPA) "Design Manual on Cold Climates Utilities Delivery" are both good references for this type of design.

Another consideration for hotter regions includes withdrawal from near the top of the tank for hot water and from the bottom when cold water is desired.

At some sites, cold regions in particular, it is advantageous to have extra supply capacity for several reasons. Acquisition of replacement parts or severe climates may hinder correction of a problem in the water supply. Some sites have to pump their entire year's water supply in a few months, requiring sizable storage capacity. This would be necessary when the water source freezes completely from top to bottom or is intermittently frozen. Redundancy in tank numbers may also be appropriate.

Water storage and supply for emergency conditions must also be considered. See Guidance 2.b.2.

b. Water supply systems

The selection of a water source will be based on availability, adequacy, quality, cost of development, and expected life of the project. Generally, the supply that can be used at the lowest first cost is preferred, especially for projects with a comparatively short life. However, in addition to first cost, the question of annual operating costs, including power, chemicals, and personnel salaries will be considered in view of the project's expected life in arriving at the final selection of source. For projects adjacent to municipalities, the municipal facilities will be investigated to determine if they are able to supply the projects and if the appropriate officials are favorably inclined toward serving the project at a reasonable cost to the Government. These investigations will consider any increase in the city's requirements because of the construction of a Government facility and because of the city's future growth and development potential. (111) 1

When a long supply line is required between the supply and the distribution system, the most economical size of main will be studied by considering the cost of construction, expected length of use, cost of operation based on power cost, and minimum use of

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critical materials. If there is already a water supply under the jurisdiction of DA, Air Force, or other Government agency, an investigation will be made to determine its capacity and condition and the possible arrangements for its use with or without enlargement. (111) 1

When new water sources are being developed, physical, chemical, and bacteriological analyses will be made to determine treatment required to make water safe and potable. Knowledge of chemical properties is essential for selection of water treatment equipment. Hard water may need softening equipment.

DCS sites are in the on-site utility category and can take advantage, due to their small size and relatively low demand, of opportunities that would not meet demands for a community supply. Such options include springs, rainwater collection, shallow wells in marginal aquifers, melted snow or ice, desalination or reverse osmosis units, and lens wells. Each situation has alternatives and requires specialized engineering.

1. Developed supplies (111) 2

Investigation of existing sources will include:

Source
Reliability of supply
Quantity developed
Ultimate quantity available
Excess supply available not already allocated
Type of treatment and capacity
Rates in gallons per minute at which supply is available
Cost per 1000 gallons
Distance from site to existing supply
Variation in pressure at point of diversion from existing system
Ground elevation at point of diversion and at point of use
Existence of contaminants
Water quality.

When existing supplies cannot be used economically, the availability, quality, and cost of both well and surface supplies will be investigated.

2. Groundwater (111) 2

An investigation to determine the availability, quality, and economy of well supplies will cover:

Reports on groundwater resources from State Board of Health, State Geologist, U.S. Geological Survey or similar agencies
Reports on rainfall (distribution, maximum or minimum intensity)
Reports from operating water companies securing supplies from the formations

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Records of available well logs, drawdown data, total pumpage from area (both seasonal and long-term), and variations in elevation of groundwater table
 Records of aquifer permeability and groundwater velocity (laminar or turbulent flow)
 Records of physical, chemical, and bacteriological analyses
 Existence of contaminating influences
 Necessity for treatment, such as iron removal, softening, corrosion control, taste, and odor
 Spacing required between wells to prevent mutual interference
 Legal clearance if required by proximity to well fields of others

TM 5-813-2 suggests that requirements for well drilling, such as specifications, will be written by persons familiar with local conditions and established practice in the area. Generally, well construction will conform to American Water Works Association Standards for Deep Wells. Prospect holes and observation wells will be no less than 2 inches in diameter and test wells will be no less than 4 inches in diameter. Test wells should be pumped after selection of the best location for development. One pumped well and one or more observation wells are required. For a permanent installation, at least one observation well should be 10 to 15 feet from the pumping well, with others 50 feet or more away. The test should run 24 hours minimally with the following data secured: (96), 13

1. Initial static water level in each well
2. Pumping rates, taken at least every hour
3. Drawdown data, taken at least every hour
4. Rate of recovery
5. Water levels at each observation well taken with an automatic recorder accurate to 0.02 feet where the formation's ability is doubtful.
6. Water samples at 0.01, 0.05, 0.10, and 0.5 times test duration, and at the end of the test.

WELL CAPACITY VERSUS DIAMETER

Capacity (gpm)	Diameter (in.)
50	6
50-300	8
300-500	10
500-750	12
750-1000	15
1000-2000	20
2000 and over	24

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At least two wells should be provided to insure an adequate supply. The yield of the wells should be at least the maximum daily consumption. The capacity of wells to service DCS sites will generally be less than 50 gallons per minute; therefore, a diameter of 6 inches is fine. The wells will be deep enough to penetrate the water bearing aquifer and permit installation of (1) an adequate length of screen and (2) pumping equipment. (96)

Well spacing should be:

Depth (ft)	Spacing (ft)
Less than 100	100
Over 200	200-1000

Earthquake zones require standby wells with standby power and water purification equipment when the total supply is from wells.

A primary concern regarding water supply from wells is adequate protection against surface and subsurface contamination.

Coastal aquifers require that overpumping be avoided to keep saltwater out of the freshwater basin. Control methods include pumping modification, artificial recharge, pumping troughs, pressure ridges, and subsurface barriers. Skimming wells are used when seawater contacts fresh groundwater on one or more sides at the following sites: islands, peninsulas, spits, etc., surrounded by or extending into the sea, and artesian aquifers which outcrop under the sea. The skimming wells should be constructed above the sea level and near the thickest section of the freshwater lens to harness the greatest available hydrostatic pressure and storage. (96) 17

Springs are another source of groundwater. Often, their yields may fluctuate and are subject to pollution. Different types include thermal, gravitational, depression, contact, artesian, and tubular or fracture. Thermal springs are not used since their waters are often highly mineralized. Collection works consist of:

1. Collection chamber - for all gravitational springs
2. Open trenches - for depression and contact springs
3. Buried pipes - for depression and contact springs
4. Wells - for artesian springs.

Generally, open trenches are not recommended. A perforated pipe is recommended for the water bearing strata in aquifers with marginal productivity.

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The following table shows different types of wells along with their characteristics.

TYPES OF WELL CONSTRUCTION (96) 15

Type	Diameter (in.)	Max. depth (ft)	Approx. yield rate (gpm)	Construction method	Location
Shallow wells:					
Dug	36 - 96	50	1 to 1500	Excavation	Unconsolidated formations or soft rock.
Bored	6 - 8	5	0 - 5	Hand auger	Same as above.
Bored	Up to 36	>100	0 - 200	Power auger	Same as above.
Driven	1-1/4 to 4	50	0 - 5	Impact driven	Unconsolidated formations with no gravel and rocks.
Jetted	1-1/2 to 3	>50	2 to 40	Water jetting	Same as above.
Drilled wells: ¹					
	Up to 24	Up to 3,000	20 - 1000 +	Standard cable tool	Consolidated rock formations.
	Up to 18	Up to 3,000	200 - 1000 +	Hydraulic rotary	Unconsolidated formations.
	Up to 48	Up to 3,000	200 - 1000 +	Reverse rotary	Same as above.

¹Rotary bit and shot drilling are sometimes used in rock; cable-tool methods are used on unconsolidated formations.

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Infiltration galleries are collectors placed horizontally at right angles to the direction of flow and are served by gravity flow. Buried pipes, tunnels or galleys, underground dams, or radial-type collectors are available.

Groundwater can be developed only under favorable geographical and hydrological conditions. Secure adequate information on the underground geologic conditions as well as hydrologic elements affecting the supply. Make a hydrology analysis to determine distribution and movement of groundwater. After gathering available information, explore the surface. Use air maps for tentative appraisal of groundwater conditions in unconfirmed aquifers. Drainage and soil maps prepared from air photos may also indicate shallow sources. Geological field reconnaissance supplemented by available geologic data is essential for evaluating the supply. This information should be interpreted by a person skilled in groundwater geology. Geophysical exploration may be desirable if further surface investigation is indicated. A qualified expert should conduct and interpret results. The following methods can be used: electric resistivity and seismic refraction. The electric resistivity method maps shallow, permeable deposits and locates subsurface saltwater boundaries. The seismic refraction method is not adaptable to small areas, as local vibrations and noises interfere. Seismic refraction has been used to determine such features as depth to bedrock, thickness of surface fracture zones, and area extent of potential aquifers. Shallow investigations (<90 feet) may permit the use of hammer seismic methods. These methods use a hammer blow on a steel plate as the energy source for surface exploration. Subsurface exploration should then be performed in the form of test drilling and electric resistivity logging to confirm favorable or unfavorable conditions and the best locations for wells and screens.

Well construction guidance can also be found in AWWA Manuals and NAVFAC DM-5.7. (96)

3. Surface water

An investigation to determine the availability, quality, and economy of surface supplies will include the following: (11) 2

Topographic maps showing total tributary drainage areas of stream or reservoir
Reports on rainfall (distribution, maximum and minimum intensity)
Reports on runoff and stream flow (variations in stream flow)
Survey of contaminating influences, including quantity, location, and degree of treatment for sewage entering stream, and quantity, location, and nature of industrial wastes entering stream

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Records of physical, chemical, and bacteriological analyses of proposed supply
Feasibility of obtaining supply without construction of a reservoir
Location of available reservoir sites and geological data relating to underlying formations that may affect foundation conditions or ability to hold water
Location and probable cost of reservoir, pumping station, supply line, and treatment plant
Plans of others to develop reservoirs on the same watershed, and water rights of downstream users.

The category "Surface Waters" covers a broad range of types: streams, lakes, rainwater, snow, etc., some form of which can be found in most areas. Ranging from clean to highly polluted, they all should be considered suspect until proven chemically and biologically safe for consumption. Different sources of surface water will predominate in any given area, with procurement methods and treatment level varying.

Surface water uses that might change the safe yield of a supply include: (96) 18

1. Conservation requirements, such as flood control, and fish life preservation; recreation
2. Pollution control requirements
3. Navigation requirements
4. Hydroelectric power requirements
5. Prior water rights

The best quality water is generally desired, even if located farther away. It is important to analyze chemical and bacterial contents along with contaminant sources. The intake site should be selected where: (96), 20

1. Water quality is best
2. The current will not threaten intake structure safety by debris, log jams, or ice jams
3. Interference with navigation in the river channel is avoidable
4. Shoals or bars will not form
5. Wind waves will not stir up mud and silt from the bottom in amounts that impair water quality.

Temperate climates will probably use streams and lakes when possible, tropical climates may find rainwater collection

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more suitable, and cold regions can melt snow as their primary source. A wide variety and number of combinations are possible.

In cold regions, surface streams can be turbid in the summer due to glacial melt, and both streams and ponds can be contaminated by animal, bird, or human activities in the watershed. The water quality in flowing streams tends to improve during the winter since there is little or no surface runoff or glacial meltwater entering the stream. The water quality in shallow lakes and ponds tends to deteriorate in the winter due to the ice's concentrating effect. If ice is formed at relatively slow rates, it will consist of essentially pure water molecules and most of the suspended and dissolved matter originally in the water will be rejected to accumulate in the remaining unfrozen liquid. In the practical case, there will always be air bubbles and microscopic inclusions of unfrozen water remaining in the ice, so rejection is not 100 percent efficient. Research in western Canada with natural freezing of brackish ponds indicated that the ice contained about 20 percent of the salts that were in the original unfrozen water. (104) (102)

Most of the DEW line stations obtain water from freshwater lakes, ponds, and streams. The arctic coastal plain has small lakes and ponds over 50 to 80 percent of the total area. Most of the ponds are quite shallow (less than 3 feet) and typically freeze solid every winter. The largest lakes seldom exceed 18 feet deep. Even if the pond or lake does not freeze solid, the thick ice formation has an adverse effect on the quality of the remaining water. If a facility is to be occupied during winter in these locations and if surface waters are identified as the potential water source, the site investigation and planning must consider the water body's wintertime status and the depth of ice that will occur. The worst case may require pumping to storage tanks during the warm summer months for winter use.

Prediction of the ice thickness is necessary for proper location of water intakes and for estimation of water quality beneath the ice in relatively shallow ponds. A preliminary estimate of ice depth can be obtained from EPA-600/8-79-027, and CRREL Special Report "On-Site Utility Services for Remote Military Facilities in the Cold Regions."

Snow melting is a possible on-site water source in winter and successful systems have been reported. However, snow collection can be labor-intensive and the energy requirements for melting too expensive unless a heat source that would otherwise be wasted (exhaust gases, chimneys, etc.) can be used. The water yield from melted snow or ice will depend on the density of the original material. Fresh loose snow might only have a density of about 0.25 grams per cubic centimeter and a water yield of about 250 liters per cubic meter (2

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gallons per cubic foot of snow). Ice will typically have a density of 0.8 to 0.9 grams per cubic centimeter with a comparably higher water yield. Some snow compaction will occur during harvesting, so a typical water yield would be about 400 liters per cubic meter (3 gallons per cubic foot). It would require about 3 liters of diesel fuel per cubic meter of snow (at 0°C) if the snow melter were 100 percent efficient.

The expense and labor involved mean snow melting should only be considered as a last resort or as a standby emergency or back-up system.

In the arctic, most annual precipitation is in the form of snow. Although the total precipitation is low, advantage can be taken of the windy conditions to induce snow drifting in the watershed of a pond or reservoir. Collection of the melting snow can then augment the summer water supply. At Barrow, Alaska, it was shown that at least 10,000 liters of water was collected for every meter of 1.5-meter high snow fence with the fences about 75 meters apart.

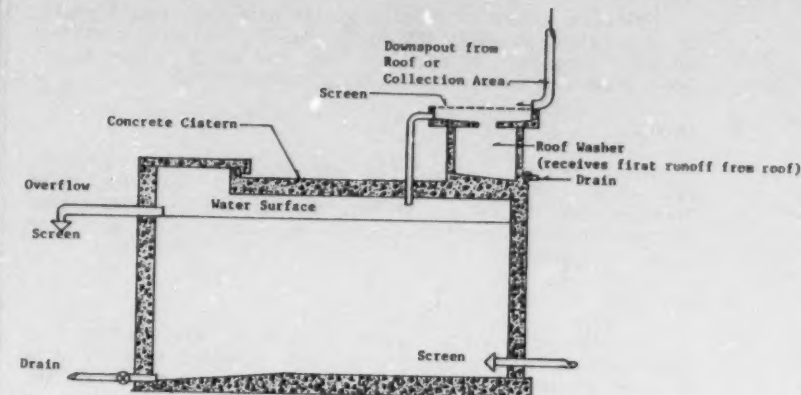
Rainwater collection and storage is possible as a seasonal or supplemental water source. It is a limited source, depending on the nature and frequency of precipitation. A minimal water usage of 10 liters per capita per day would require a catchment surface area of 23 square meters per person to supply annual needs. The following equation can be used to determine the catchment area required:

$$A = \frac{(q)(N)(d)}{10P}$$

where A = catchment area required (m²)
 q = daily water usage (l/d)
 N = number of people
 d = number of days water service is required (d)
 P = annual rainfall at the site (cm).

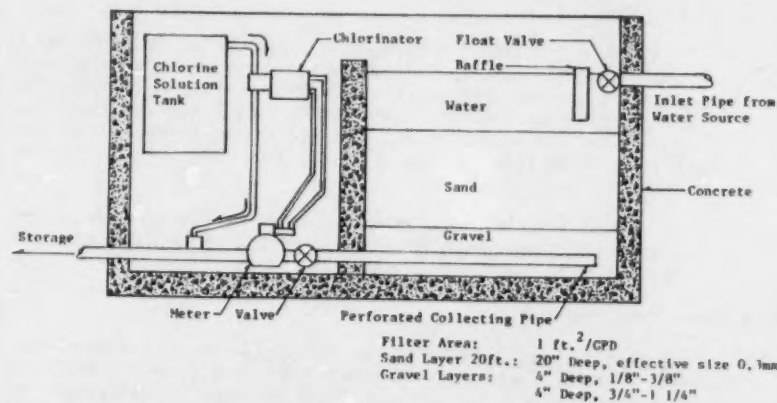
The concept is most feasible for isolated structures with a relatively large roof area and limited water needs. The following figure illustrates the design concepts for a rainwater collection cistern (the roof washer box must be drained after each rainfall event).

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RAINWATER COLLECTION WITH A CISTERN. (104) fig. 2

It is prudent to filter and disinfect collected rainwater or water obtained from other on-site surface sources such as ponds or streams. The following figure illustrates the basic design concepts for a simple gravity filter and chlorination system for on-site use. Chlorination could be with solution feeders as shown or with an erosion-type tablet chlorinator.



FILTER-CHLORINATOR FOR SURFACE WATER AND RAINWATER SOURCES. (104) fig. 3.

guidance WATER SUPPLY IMPACT/2 Storage

Other considerations regarding water supplies include water corrosivity, total freezing, ice damage, and frost heave protection.

C. Water treatment systems

Systems designed for DCS sites should be as simple as possible and still meet safety standards. The National Interim Primary Drinking Water Regulations and the secondary regulations, or those of the host country, if more stringent, determine the treatment level in meeting standards. Ideally, simple chlorination or filtration plus chlorination would be adequate for on-site use. Other equipment may be required to meet special needs, such as:

- Water softeners
- Pressure filters, often combined with potassium permanganate chemical feed for iron removal
- Disinfection equipment
- Reverse osmosis units for demineralizing saline or brackish water
- Equipment made for temperate climates but adaptable to tropical or cold regions.

Remote locations have used diatomaceous earth filters, ceramic filter tubes or cartridges, and packaged multimedia pressure filters (with automated time switch control) for service backwash and rinse.

Very turbid water may require a centrifugal separator to achieve acceptable water quality.

Water treatment is a specialized field of sanitary engineering, and expert opinions will be obtained in planning this work. The water's chemical and physical properties have direct bearing on the method of water treatment to be selected. Board of Health officials are familiar with accepted methods of water treatment and offer a source of valuable information for selecting the water treatment method for a specific project. In addition to the usual treatment for clarification, color reduction, bacteria removal, and sterilization to insure delivery of a safe, potable water, consideration will also be given to the need for special treatment to protect pipe lines, water heaters, plumbing fixtures, and other equipment against scaling, corrosion, staining, and "red water" difficulties. See also TM 5-813-3 and NAVFAC DM-5.7.

All units of the water supply system must be sterilized before initial use. Included are:

- Pipes
- Filters
- Wells
- Storage tanks
- Other units

guidance WATER SUPPLY IMPACT/3 Distribution

Chlorine is the agent of choice and TM 5-813-3 provides additional guidance.

3.a. Storage and pressure

The entire building shall be on an independently pressurized system.

b. Site distribution systems

Water service connections to facilities shall be made with underground piping, extending from an acceptable water source that can accommodate the design load to a point 5 feet from the building. The service connection shall be metered. Minimum cover over pipes will be 4 feet in grassed areas, 3 feet under pavements and 4 feet under railroad tracks. When frost depths are equal or greater than the above minimums, the cover shall be at least equal to the frost depth plus 6 inches.

Water supply mains shall cross above gravity-flow sewer lines when possible, and shall always cross at least 2 feet above force mains or inverted siphons. When mains cross under gravity-flow sewers or above force mains or inverted siphons, the sewer lines will either be fully encased in concrete for at least 10 feet on each side of the crossing or will be pressure pipe with no joint located within 10 feet of the crossing. The distances are to be measured horizontally, perpendicular to the service line. All portions of the building shall be protected by at least two fire hydrants located within 226 feet. Existing fire hydrants shall have hydrant flow tests conducted in accordance with TM 5-660, pages 171, 172, 201, 202, to verify the existing water system's ability.

No water supply mains shall be constructed within 10 feet of a sewer line, unless the bottom of the service lines is more than 12 inches above the top of the sewer line. In that case, the minimum separation is 6 feet, measured perpendicular to the main.

1. Sizing

The service connection shall be sized in accordance with the following:

Quantity - Based on peak flow as determined from the number of fixture units within the building, which is based on interior mechanical, operational, and fire flow requirements.

Pressure - Based on pressure required inside the building, as determined by internal mechanical requirements at locations shown on the site plan.

Minimum size - 3/4-inch nominal diameter.

guidance WATER SUPPLY IMPACT/4 Conservation

Friction losses - Computed by the Hazen-Williams formula, using C values shown in AFM 88-10, Vol 5. Velocity shall not exceed 8 feet per second, in either the water supply mains, water distribution lines or service connections.

2. Valves

Water service piping shall have a valve with a cast iron valve box installed on each service line near the main. Pressure reducing valves, if required, may be installed either on the main or on the individual lines to the units, whichever is more economical.

3. Disinfection

All water service lines require disinfecting by chlorination in accordance with AAWA Standard C601-77 at a minimum pressure of 200 pounds per square inch (or at the design working pressure if greater than 200 pounds per square inch) plus appropriate allowance for water hammer.

Also see NAVFAC DM-5.7 and DM-5.8 or equal, except regarding the following: (92) 12.1-11

Water supply - Hauling water is not an acceptable means of supplying water to a permanent electronic facility.

Pipe - When metallic pipe and reinforced concrete pipe are inappropriate at a particular site, this will be indicated in the project BESEP.

Lawn irrigation - Lines for this purpose normally are not provided.

Fire protection - Fire hydrants will be at least 25 feet, preferably 50 feet, away from the building and located so each building can be reached with 300 feet of fire hose. Smaller buildings away from the main facility will not require water supply for fire protection. For DCS sites, water storage for fire will be most of the water stored. See SB3 for further information.

Conformance to regulations - Water supply and wastewater disposal systems shall conform to applicable local, State, and Federal requirements and regulations.

4.a. Water reuse options

Devices and concepts exist for reusing water in various ways, generally using lower quality water for functions not requiring the best available. For example, bath or laundry wastewater may be reused for toilet flushing after minimal treatment. Other uses of lower quality water include irrigation, dust control, subsoil moisture for electrical grounds, vehicle washing, and construction

guidance WATER SUPPLY IMPACT/4 Conservation

(earth compaction and concrete preparation). Washing machines often are able to recycle water; a complete recycle laundry is being developed for field use in the Army. Shower recycling for bathing purposes also is being developed for the Army field use. Complete water recycling from blackwater to potable is possible, but is technologically complicated and expensive. For remote DCS sites, complicated and expensive recycling schemes will be avoided. Section 4.b. in guidance of SBI gives further details on some of the systems available.

b. Conservation devices and system equipment

Water conservation at on-site systems tends to be more effective than in large community systems since the occupants are more directly responsible for their own supply and can more easily recognize the benefits of conservation.

Water conservation is of primary importance when a DCS site must react to a hostile environment or during periods of inadequate supply or storage. Conservation is necessary if the facility is to remain operational during these periods of isolation.

Water conservation methods include eliminating nonfunctional water use, devices and equipment, and wastewater recycle/reuse systems. Nonfunctional water use includes wasteful habits such as running water while brushing teeth or using the toilet to flush a cigarette butt. Education of the users and command directives can help eliminate this waste. Leaks from fixtures (dripping faucets or leaking toilets) may waste large volumes of water on a daily basis and should be corrected. A leak detection program should also be instituted to uncover underground leaks on a periodic basis. Water pressure through piped systems is adequate at 40 pounds per square inch. Extra pressure can result in waste. The majority of water use will be for toilet flushing and personal hygiene. If a barracks is present, additional water will be consumed in kitchens and laundries. Other methods for conserving water include air cleaning (compressor) for vehicles with minimal water consumption. For food service, dry cleanup should precede wet cleanup with garbage disposals eliminated.

The following are methods of water use amenable to conservation. Choices from these can reduce the water consumption of a DCS site, permitting it to function with less water. It must be noted that not all alternatives apply to every situation.

1. Toilet alternatives (102) B-8

Composting (large) - Microorganisms digest kitchen garbage and human wastes, producing fertilizer. (See also "Wastewater impact.")

Advantages. End product, compost, can be used as fertilizer. Reduces pollution. No water, sewer, or electrical hookups required. No moving parts and little maintenance.

guidance WATER SUPPLY IMPACT/4 Conservation

Disadvantages. High initial cost for unit and installation. Unit is very large, requiring considerable basement space.

Synthetic fluid - System uses special chemical fluid or mineral oil as flushing medium. Waste materials settle out in holding tank and fluid is filtered and recycled to conventional toilet. Waste must be pumped out about once a year.

Advantages. Uses conventional toilet and plumbing but no water. Can be used in conjunction with an incinerator to destroy concentrated wastes.

Disadvantages. High initial cost for unit and installation. Requires significant space and is relatively complex. Requires replacement of lost fluid and addition of odor control chemicals. Energy requirement for pumps and incinerator, if used; otherwise, waste must be pumped out for disposal.

Treatment systems (recycle) - Treated and filtered toilet and other wastewater are recycled for toilet flushing. Sludge in tank must be pumped out every year or two.

Advantages. Uses little or no fresh water. Some will accept wastewater from other fixtures.

Disadvantages. High maintenance and capital cost. Requires filters, disinfectant, dye, pumps, and electrical power.

Shallow trap (conventional) - Wastes are siphoned through a trap by a sudden rush of water from the tank reservoir. Unit has a shallower trap and smaller reservoir tank than typical.

Advantages. Sanitary, odorless, relatively easy to repair and inexpensive to buy. Uses approximately 33 percent less water than conventional.

Disadvantages. Uses large quantities of water to transport small amounts of waste. Ultimate disposal of sewage can be a problem. Requires pressured water supply and piped gravity sewage collection system.

2. Toilet retrofits

Improved float assemblies - Replaces existing conventional float ball and fill valves, allowing water levels to be lowered and adjusted to use the minimum amount of water necessary for efficient flushing.

Advantages. Improves flushing efficiency and some will

guidance WATER SUPPLY IMPACT/4 Conservation

facilitate leak detection. Potentially more durable than conventional replacement equipment due to less wear. Valve on leak signaling type is always in fully open or closed position, therefore, is quieter than slow closing conventional ball cocks.

Disadvantages. Water savings are essentially limited to leak elimination. Slightly higher cost than conventional replacement equipment.

Dual-flush mechanisms - Single-action type can be a counterweight, floating cylinder or air bleeder mechanism that manipulates the flush valve stopper. When toilet is flushed normally, only part of the flush water is released. For a full tank flush, the flush handle is held down. Double action types replace existing flush valve assembly. The flush handle moves in one direction for low volume flush (liquid wastes) and in the opposite direction for full flush (solid wastes).

Advantages. Allow for user choice in flush quantities. Can be used in conjunction with dams.

Disadvantages. Single-action types require handle to be held for full tank volume flush. Air bleed types could become clogged with water deposits or dirt. The double action flush mechanism is difficult to install and since it is not adjustable, it may not give an adequate flush in all toilets.

Replacement tanks - Mounts on existing toilet bowl replacing the whole reservoir tank with a pressure tank cartridge and cover. Water entering the empty tank compresses the air inside, stopping when water and air pressure are equal. When toilet is flushed, compressed air and gravity force water into the bowl.

Advantages. Uses about half the water used by a conventional toilet tank.

Disadvantages. Expensive and more difficult to install than other devices. Somewhat noisy at high pressure and may not work adequately on systems with water pressure less than 240 kilopascals.

Bricks and plastic bottles - These are filled with water and weighted with small stones or completely filled with sand or gravel and inserted into the toilet tank. For each flush they displace and, therefore, save water equal to their volume.

Advantages. Inexpensive, easily installed homemade devices usually consisting of discarded household items. If inadequate flushing results, plastic bottles can be cut reducing the size until the toilet flushes satisfactorily.

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Disadvantages. Bricks deteriorate in water and particles will clog water jets and lodge under the flush valve causing a continuous leak. They can also crack the tank if dropped or fall over, and multiple bricks will inhibit the flow of water around them. Bricks are not recommended. Plastic bottles can shift and interface with the flushing mechanism and if filled with sand and not properly sealed, escaping sand can lodge under the flush valve resulting in a continuous leak.

3. Water conservation devices (102) B-15

Pressure regulator - Adjustable spring is used to change pressure on a rubber diaphragm which, in turn, maintains the building water pressure at a preset value below the water main pressure.

Advantages. Used where excessive water main pressures could burst fittings or cause excessive noise, vibration, and leakage. Reduces water use and waste since maximum flow rate is reduced. Provides constant water pressure to building.

Disadvantages. Lower pressures and therefore flow rate will increase time to obtain fixed volume of water.

Water circulation - Water pipes in the building or particular area are looped back to the hot water tank and a small pump circulates water within the loop. Buildings with individual water systems only need a return line from each faucet to the cistern and a valve to allow draining. Faucets or other water outlets tap off of the loop. Usually only done for hot water pipes.

Advantages. Eliminates need to waste cooled water standing in line between the heater and faucet before hot water is available. Provides hot water instantly since supply loop is maintained at hot water heater temperature. Circulation pump can be put on timer of thermostatic control to reduce heat loss and pump operating time.

Disadvantages. Retrofitting existing systems may be impractical. Heat losses increase particularly for uninsulated pipes and for circulation pumps not on a timer. Water circulation requires a pump.

Recycle systems - Wastewater is collected and treated for reuse. Some systems only recycle gray water and may not recycle for drinking and cooking. Treatment may include biological methods, chemical precipitation, filtration, carbon absorption, reverse osmosis, distillation, disinfection, and other methods.

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Advantages. Recycling reduces total water requirements to zero or minimal. Building can be independent of water and sewer systems.

Disadvantages. Very high capital and operating cost. Complex, high technology beyond most householders abilities to maintain. Recycle of wastewater, except for toilet flushing, is a health hazard and is not aesthetically acceptable by many. Requires energy, chemicals, and scheduled servicing by qualified personnel. Takes up space and may require alternative system for emergencies.

5.a. Analysis of surface and subsurface groundwater and soil conditions

- The natural drainage features and soil characteristics of proposed sites and expected climate extremes must be considered since these factors affect the work that will be required to prepare a selected site for an earth terminal installation. (38) 3-8

The storm drainage system, including gutters, drain, inlets, and culverts, shall be designed to carry the anticipated runoff, including runoff from melting snow, and inlets shall be provided where necessary to intercept surface flow. The building up of undeveloped areas may have a noticeable effect on installation drainage facilities; major alterations or extensions to storm sewers and drainage channels may be required because of the location and design of new facilities. (93) 4-9

For proper drainage, all phases of erosion, sedimentation, and dust control will be included as an integral part of the design and funding in every construction project in which these considerations are involved. This will include both temporary erosion and sedimentation control measures during construction and permanent stabilization remaining in effect after construction. Each siting and grading problem will be studied carefully to minimize grading and take maximum advantage of existing topography, vegetation, and topsoil. Provisions for controlling potential sources of environmental pollution caused by construction activities shall be included in design specifications. See Federal Construction Guide Specification 01501, Environmental Protection; grading criteria appear in Chapter 15, Section C.

Soil sediment erosion from construction sites will be minimized by effecting combinations of the following procedures as applicable:

1. The area of land exposed to erosion at any one time during construction and the period of exposure will be held to the minimum that is practical.

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2. Apply temporary mulch on denuded areas of the construction site immediately after rough grading is completed.
3. Construct sediment basins to precipitate silt from storm runoff before it leaves the site.
4. Construct temporary grade stabilization devices such as diversion berms, water spreaders, sodded channels, and asphalt flumes.
5. Install permanent storm drainage systems and base course for all pavements at the earliest practical time.
6. Stabilize vegetation immediately after finish grading using a two-step procedure if necessary. That is, apply the mulch regardless of season, and delay seeding, sodding, or sprigging and fertilizing, if necessary, until the season most favorable for establishing grass or ground cover.

For computation of runoff, the standard rainfall intensity-duration curve shall be 2.36 inches per hour.

The minimum time of concentration for rainfall intensity shall be 10 minutes for paved areas and 20 minutes for turfed areas.

Foundation drainage pipe shall be provided along the periphery of the exterior wall footings and as may be required underneath the building interior.

See NAVFAC DM-5.3 or equal, except for the following: (92) 12.1-10

1. Runoff: Calculation of storm water runoff shall be based on a storm with a 50-year design frequency.
2. Pipes: Metallic pipe and reinforced concrete pipe are inappropriate at some sites. Their use will be determined by project requirements.
3. Drainage: Swale drainage shall be used to the greatest extent possible. Minimal design velocities shall be maintained to avoid damage to ground planes.
4. Exceptions: Storm drain pipe shall not be used through an antenna ground plane.

b. Change in water table depth

1. Wind laid

Sand dunes - Not much change, as the sand is permeable and water can easily make its way to recharge it. However, when located next to a saltwater body, it is probably underlain by saltwater, in which care great case must be taken: (a) not

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overdraw for water supply use, otherwise saltwater will be drawn into the water system; (b) leave large amounts of open space available as a freshwater recharge area; (c) be careful that excavation cuts do not increase loss of freshwater as springs (particularly near the contact line of land and water on the shore). Make sure there are no leaks; any pollutants will quickly reach the water table because of the high percolation rate.

Loess - Can change easily if not permitted easy drainage. An increase in water table will cause stability problems (see "Landform stability probability"), but it may also be lowered easily using drainage tiles to increase or insure stability.

2. Water laid

Flood plains - See "Ease of sedimentation."

Terraces - Although often associated with river flood plains, the water table is low and the soils are well drained and dry. Therefore, there is little potential for change.

Deltas - Low potential.

3. Alluvium

Alluvial fans - Very high changes, as these are generally found in arid areas and can be drawn down easily with overuse for a water supply. See also "Groundwater change flow/amount."

Valley fill - Change not as probable as in alluvial fans, as this is much deeper in general and sits on an impervious bedrock layer which holds it well.

Continental alluvium - See "Valley fill."

4. Freshwater deposits

Lake beds and playas - Change potential varies a great deal naturally, but surfaces often are susceptible to use of agricultural drainage tiles to bring level down to a maximum.

Organic deposits - Must be drained for most development. Generally located in wet or damp areas.

5. Marine

Coastal plains - Low potential for change, as granular material is usually present with abundant recharge potential. See "Groundwater pollution."

Beach ridges - Little potential, as a water supply is

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nearby. See "Coastal plain, groundwater pollution."

Tidal flats - Little change, as they often are at or near the ground surface and flooded by tides for renewal. However, the top layers can be replaced with a better drained material for foundation support, and the fill can be raised well above the water table.

6. Metamorphic

Slate - Change depends on local conditions.

Shist - Change depends on local conditions.

Gneiss - Change depends on local conditions.

7. Glacial

Till (end/ground moraines) - Water table can be lowered slightly with agricultural tiles; however, layout may cause problems.

Drumlins - Very little change, as the water table is already very deep in the soils, plus the drainage is slow, making them a poor source of water.

Eskers and kames - Already very deep and dry due to courses comprising them.

Outwash - Little change, as the water table runs in layers of permeable coarse material and can be recharged easily.

Lake beds - Little change, as these are low land, well fed by water with slow drainage.

Permafrost - Extremely high potential for change as the water table often lies on the ice layer which is very susceptible to change. Also, it can be overdrawn so that when it freezes in the winter, less is available to freeze and subsidence will set in or be speeded up.

8. Igneous

Granite - It is possible to create new points by blasting to drain the water supply, but not practical. The best place to look for water is in the intersection of joints, but yield is not great because the flow system is constricted.

Basalt flows - Can be used, as the materials are fine, often with a hardpan in the soil B-horizon. Also the lower coarse materials are good for water supply, but these areas drain very quickly.

guidance WATER SUPPLY IMPACT/5 Drainage**9. Sedimentary**

Sandstone - Low potential for change, as sandstone is usually highly permeable and recharges easily.

Shale - Slight change, as the infiltration rate is very low.

Limestone - Great, as opening a new underground water route may lower local water table.

Interbedded - Usually depends on thickness of carrying deposit and recharge ability. Particularly in tilted formations, care should be taken not to interfere with groundwater supply recharge located mainly in the limestone as sandstone deposits.

Coal - No comment.

C. Susceptibility to change in surface water flow**1. Wind laid**

Sand dunes - Slight, as a large percentage of water infiltrates the surface rather than running along well defined ravines.

Loess - Well drained vertically, but compaction by heavy equipment will cause soil to be semipermeable, meaning more surface water volume must be handled. This may also change the drainage pattern or increase erosion.

2. Water laid

Flood plains - Relatively changeable due to flooding. Natural drainage ways should not be assumed to be stable features for building water-related structures. Dredge channels are common. Often drainage ways flow over very porous areas or disappear underground (swamps, wet areas). They may be filled out but serve an important purpose in water purification and should be preserved as much as possible.

Terraces - Not usually a problem.

Deltas (birdsfoot and arc) - High discharge may open up new drainage ways and abandon others. Thus, do not necessarily consider the drainage ways permanent features.

(Estuarine) - Generally stable but can be dredged easily, inducing bank erosion. See "Clearing of natural vegetation."

3. Alluvium

Alluvial fans - Channels change constantly. They flow

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down one direction, depositing material that fills the bed above the bank levels, which causes it to switch to another area. Therefore, the stream flow cannot be predicted, making a dangerous situation for any development.

Valley fill - Much less likely than alluvial fan, as sources are not as constricted and, more importantly, slope is more gentle. However, braided pattern is still subject to change.

Continental alluvium - Relatively stable, but regional water table drawdown can cause the rivers to dry up (they will go below ground), which is not necessarily bad as in dry areas, where storing water underground is more efficient.

4. Freshwater deposits

Lake beds and playas - No comment.

Organic deposits - Ditching for faster water removal may cause subsidence. See "Groundwater flow/amount change."

5. Marine

Coastal plains (uplands) - High percolation rates cause low susceptibility.

(Lowlands) - Generally have a high water table, often near the surface. Drainage channels can cause it to be lowered.

Beach ridges - Land is hummocky with internal drainage.

Tidal flats - Often dredged to channel the water. This moves water through faster which dries some of the upper layers, changing the water-air life balance. There is a variety of animal and plant life here, particularly in marshes.

6. Metamorphic

Slate - Not usually a problem.

Shist - Not usually a problem.

Gneiss - Most drainage is on the surface. Soil compaction in construction will cause increased runoff. Blasting for construction can also cause rock fractures, which can cause surface drainage to become subsurface.

7. Glacial

Till - Not usually a problem

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End/ground moraines - Often has karst-like depressions and swamps resulting from the deranged topography. Usually can be drained using agricultural drainage tiles.

Drumlins - No susceptibility; drainage is almost entirely internal.

Esker - Drainage mainly internal.

Kame - Drainage internal or in short ravines on the slopes.

Outwash - See "Alluvial fans."

Lake beds - Poorly drained and generally very flat so that artificial drainage (ditching) is often done.

Permafrost - Highly susceptible; see "Erosion by water" and "Clearing." Thawing will subside and a ravine may become a pond.

8. Igneous

Granite - Relatively stable.

Basalt flows - See "Change in water table depth."

9. Sedimentary

Sandstone - Low, as the ravines are usually deep and well established.

Shale - Can be used, as the surface material is soft and not controlled by bedrock.

Limestone (arid) - Flash floods are common and destructive.

Interbedded - Depends on local conditions.

Coal - No comment.

d. Susceptibility to groundwater change in flow/amounts**1. Wind laid**

Sand dunes - No problem except when near saltwater (in which case, see "Susceptibility to change in water table depth.")

Loess - Make sure no impermeable subsurface obstructs water flow, thus raising or lowering the water table. See "Landform stability probability."

guidance WATER SUPPLY IMPACT/5 Drainage**2. Water laid**

Flood plains - See "Ease of sedimentation."

Terraces - See "Change in water table depth."

Deltas - Little, as they are generally surrounded by or near a body of water.

3. Alluvium

Alluvial fans - Flow may be partly buried by coarse slope debris. If so, a head might develop by pressure. A road cut may cause springs to appear, but will also cut off flow to down slope sections of the water table, lowering it, impeding vegetation, and beheading an aquifer.

Valley fill - The water table supply and recharge abilities can be overdrawn. This must be determined on site and from that, development limits must be set to insure continued supply.

Continental alluvium - See "Valley fill" above and "Landform stability probability."

4. Freshwater deposits

Lake beds and playas - The percolation rate is very slow, so as long as the recharge areas are not disturbed, the amount will stay constant. Slow percolation also limits daily water extraction.

Organic deposits - Lowering the level causes oxidation and decomposes organic matter, resulting in shrinkage and subsidence. Swamps act as aquifer rechargers and water purifiers. If they are filled or cleared, there is great likelihood that both flow and amount will change.

5. Marine

Coastal plains - See "Groundwater pollution."

Beach ridges - Naturally well drained; adjoining or underlying landforms determine susceptibility.

Tidal flats - Can often be ditched to lower, but most of the material is usually saturated.

6. Metamorphic

Slate - Depends on local conditions.

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Shist - Drainage is through interconnected rock fractures and is usually of small volume and slow. If this source is used, it is susceptible to change.

Gneiss - Main groundwater supply is located in rock fractures, so these are the areas limited for water supply. If the limited area of water flow recharge is slowed, water quantities taken from here will be of low yield or will draw down the supply.

7. Glacial

Till - Not usually a problem

End/ground moraines - No comment.

Drumlins - Little.

Eskers and kames - Little problem, as groundwater is usually found in the underlying layers.

Outwash - See "Alluvial fans" above.

Lake beds - Not usually a problem.

Permafrost - Drains well in sand, gravel, and rock.

8. Igneous

Granite - Drawdown in the constricted jointing channels may cause water to reverse direction locally, lowering the groundwater content.

Basalt flows - See "Susceptibility to change in water table depth."

9. Sedimentary

Sandstone - Layers are often used as water supply sources, for which they are well suited. However, they are sometimes overused, lowering available water pressure or drying out the interstices, particularly if total pumpage is from numerous wells.

Shale - Slight.

Limestone (arid) - Can be overdrawn. Care must be taken to determine supply abilities and limit withdrawal to that amount.

(Humid) - High flow means much solution cavern forming. (See "Susceptibility to groundwater pollution.")

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Interbedded - When composed of clay, limestone, it will have permeable limestone with nonpermeable clay, which causes surface springs at the contact zone.

Coal - No comment.

①. Erosion susceptibility by water**1. Wind laid**

Sand dunes - A minor concern in most cases, as precipitation usually infiltrates the ground quickly.

Loess - Some problem. Keep under vegetative cover as much as possible. River banks will naturally erode to vertical walls. This is due to the interlocking loess grains. Because of the water-saturated lower base, banks are unstable and liable to slump.

2. Water laid

Flood plains - Flat areas and much greater flooding impact makes erosion relatively unimportant.

Terraces - Generally stable.

Deltas (birdsfoot, arc, and estuarine) - High susceptibility, but in most cases, sedimentation is more of a problem. See "Landform stability probability."

3. Alluvium

Alluvial fans - As a land changing process, water is much more important than wind, although fans are usually found in dry areas. It brings materials down from the mountains (including large boulders), causing erosion, sedimentation, and changes in the direction of water drainage. However, the net effect of water is to build up the land (see "Ease of sedimentation").

Valley fill - See "Alluvial fans."

Continental alluvium - See "Alluvial fans."

4. Freshwater deposits

Lake beds and playas - Little erosion, as the land has little slope and the soils are plastic and cohesive.

Organic deposits - Fibrous nature plus slow water movement due to flatness makes it very resistant.

guidance WATER SUPPLY IMPACT/5 Drainage**5. Marine**

Coastal plains - Little erosion.

Beach ridges - Soil is too pervious and coarse to create much problem.

Tidal flats - Fast flowing streams will eat away at the banks. See "Surface water flow."

6. Metamorphic

Slate - Only a concern on steeper slopes.

Shist - Because of the flat plate structure, water can penetrate rather easily and attack the minerals (particularly pyrite), which oxidize and expand. This separates the layers and finally forces them to break off into "rotten rock." See "Ease of sedimentation."

Gneiss - Rather resistant, although the loose soil material can be moved easily.

7. Glacial

Till - Rather low susceptibility, as it is often flat; however, raindrop impact and sheet erosion do contribute to erosion of exposed areas.

End/ground moraines - Erosion found in some. Mainly, the water system is attempting to integrate itself and interfering with this process will cause headward erosion to exist elsewhere.

Drumlins - Little, as the material is a compact mixture.

Eskers and kames - Little, as materials are coarse.

Outwash - Low, but some of the sands can be moved with relative ease (those sections in about the middle and lower end of the landform). These areas have linear depressions that are glacial stream beds in sand, now eroded smooth.

Lake beds - Low, as it is flat. However, stream ditches and tributaries may try to extend themselves; do not interfere with this extension, or erosion will be uncontrolled. Sometimes drainage is entirely internal, in which case there is no erosion.

Permafrost - Usually pretty flat, but where it is not, it is very susceptible because the surface thawing is a rather loose mixture unless frozen year-round. It is usually covered with a thick layer of tundra debris with properties similar to organic materials.

guidance WATER SUPPLY IMPACT/5 Drainage**8. Igneous**

Granite - Steep slopes and loose materials make erosion a problem.

Basalt flows - Depends on local conditions.

9. Sedimentary

Sandstone - Not great; soil is absorbent and the rock is resistant. The soil is so absorbent that the water table is usually found in bedrock only.

Shale - Sheet erosion and gullying are problems. For construction, place sedimentation traps in ravines.

Limestone (arid) - Water erosion from sudden storms is great and it will cut the river bed and banks like any arid climate flash flood.

(Humid) - Solution by water is very great. It weakens the ground surface's support ability, sometimes to the point of collapse (see "Landform stability probability").

Interbedded - Same as for the individual rock units.

Coal - Exposed soil piles have a high slope and no vegetative cover, and therefore, high erosion potential.

f. Ease of sedimentation**1. Wind laid**

Sand dunes - Not applicable.

Loess - Well suited to settling out in water bodies. It is important in siltation of small streams and streamlets during construction. Siltation traps could greatly decrease this problem.

2. Water laid

Flood plains - Extremely susceptible, particularly from construction activities that cause a decline in the water table. For the water supply, results are increased pumping lift costs and shutdown time to deepen settings, curtailed pumping to minimize wall interferences, abandoned wells, and reduced aquifer yields.

Terraces - Little, because of the particles' coarseness--unless it is covered with a layer of loess.

Deltas (birdsfoot, arc, and estuarine) - A major factor in the formation and growth of these features. If it is

guidance WATER SUPPLY IMPACT/5 Drainage

hampered, erosion by flood-curring may become the dominant process.

(Arc only) - Generally coarse material; therefore, sedimentation is relatively less important.

3. Alluvium

Alluvial fans - Formed by rain and melt waters bringing large quantities of debris from the mountains suddenly. The constricted mountain valley allows water to travel down slopes (fast) in large quantities (thus carrying much debris) in a short period (flash floods). As it enters the valley opening, it spreads, decreasing carrying capacity (drops largest load components) and spreading further, drops smaller and smaller particles out to the fan edge where the finest materials are laid.

Valley fill - An overlapping of alluvial fans from adjoining mountain valley sources. This happens as alluvial fans become older and thus spread more and decrease the slope. Also, a greater proportion of fines (silt and clays) is present from the longer weathering. See "Alluvial fans."

Continental alluvial - Another step in the aging structure. See "Valley fill" and "Alluvial fans."

4. Freshwater deposits

Lake beds and playas - High, as the large percentage content of fines will fill in slow flowing areas of water bodies.

Organic deposits - Not much sedimentation as there is usually only a small drainage area and often no feeder stream. The ground surface is built of decaying vegetation. If it gets too far above the water level, it dries, becoming fire prone, burns and lowers its level, enriching the nutrients available and increasing its time of existence as a swamp.

5. Marine

Coastal plains - Depends on local conditions.

Beach ridges - See "Susceptibility to flooding."

Tidal flats - Primary means of formation for mud flats. Dredging will cause water to flow more quickly, thus lessening flooding (hence sedimentation) and opening the way for erosion.

guidance WATER SUPPLY IMPACT/5 Drainage**6. Metamorphic**

Slate - No comment.

Shist - The decaying rock contributes large, fresh amounts of material to slopes that can be washed into streams and ponds easily. Although cuts caused by construction do not directly contribute to sedimentation, the exposed, decaying rocks will slowly fill in streams, so this impact must be controlled even after construction.

Gneiss - Construction will cause the loose soil to erode and silt in the streamlets so that during construction, silt-traps should be placed in the ravines and emptied periodically.

7. Glacial

Till - Not usually a problem.

End/ground moraines - Relatively high, as the drainage system is adjusting itself.

Drumlins - Little or no sedimentation.

Eskers and kames - Particles are too coarse.

Outwash - Landform created by sedimentation from a melting glacial moraine front. The coarsest deposits are found near the moraine edge and the finest (fine sands) toward the opposite side of the unit.

Lake beds - Any slowing of the water in its course (such as a pond) will be liable to high sedimentation as the drainage ways are filled with sediment from large areas (the drainage density is low).

Permafrost - Not usually a problem.

8. Igneous

Granite - Some sedimentation. When the mountain ravines enter a flatter course, they drop their load to make alluvium.

Basalt flows (arid) - Not great.

(Humid) - Low.

9. Sedimentary

Sandstone - Not usually a problem.

Shale - Very great, particularly in ponds. Try to keep the areas near stream banks vegetated to trap materials before they reach the stream.

guidance WATER SUPPLY IMPACT/5 Drainage

Limestone - No comment.

Interbedded - Depends on local conditions.

Coal - If allowed to drain directly into streams, the eroded load will be deposited there and in ponds. Siltation traps should be used anywhere there is exposed soil.

g. Runoff based on slope, soil type, and vegetative cover**1. Wind laid**

Sand dunes - Very little runoff; most infiltrates to the water table.

Loess - Moderate. It is a very porous material once water enters it.

2. Water laid

Flood plains - Depends on type of soil present. Usually little due to flat land and previous materials (resulting in high water table).

Terraces - A great deal of runoff is absorbed by the ground, although terraces have developed drainage systems.

Deltas (birdsfoot) - High, but since bodies of water are usually nearby, little impact results.

(Arc) - Low, as the coarse soil absorbs water well.

(Estuarine) - Flat and absorbent, therefore little runoff. Standing water is not uncommon.

3. Alluvium

Alluvial fans - Although most of the material is very coarse, the speed at which water moves over it allows a high runoff percentage. Only lower portions of the fan absorb the water overflowing it (good place for wells), so that most water is absorbed by the time it reaches the fan edge. Runoff from direct rains is much less.

Valley fill - See "Alluvial fans."

Continental alluvium - Most water is either absorbed by the land or evaporated.

4. Freshwater deposits

Lake beds and playas - Low because of extreme flatness.

Organic deposits - Low.

guidance WATER SUPPLY IMPACT/5 Drainage**5. Marine**

Coastal plains - Low.

Beach ridges - See "Susceptibility to flooding."

Tidal flats - Low.

6. Metamorphic

Slate - Relatively high.

Shist - Moderate; much of the water is absorbed by rock.

Gneiss - See "Clearing of natural vegetation."

7. Glacial

Till - Depends on local conditions.

End/ground moraines - Moderate.

Drumlins - High, decreasing with more vegetative cover.

Esker - Moderate; coarse materials but steep slopes.

Kame - Lower; coarse materials and less steep slopes.

Outwash - Very low and internal as the coarse material and slight slope make infiltration high.

Lake beds - Low.

Permafrost - Usually very low.

8. Igneous

Granite - High slopes, usual lack of vegetation and coarse soils generally cause high runoff.

Basalt flows (arid) - Low due to coarse materials.

(Humid) - Moderate.

9. Sedimentary

Sandstone - Moderate, as slopes are steep. Often associated with sandstone, though, which absorbs water readily.

Shale - High, causing sheet erosion problem (see "Erosion susceptibility by water").

guidance WASTEWATER IMPACT/1 Wastewater Sanitary

Limestone (humid) - Normal, unless karst topography is present, in which case all the water will either be ponded or go directly underground.

Interbedded - Depends on local conditions.

Coal - No comment.

1.a. Determination of wastewater sources and rates of quantities produced

Sewage systems of existing facilities should be investigated to determine if they will accommodate the extra load imposed by the new facility. Installation and engineering plans for new sites must include extension into an adequate existing sewer system or the installation of a properly sized and constructed septic system. A soil percolation test should be conducted at all new sites without existing sewer systems to determine if the land can accommodate a septic system. Local sanitation engineers should be consulted for construction requirements, inspection, and approval of septic systems. (87) 4.3.3.

Calculation of wastewater flows to a treatment facility is usually based on the following factors:

- o Number and type of facilities to be served
- o Water usage rates for each facility type
- o Consumptive use factors
- o Visitation schedules (actual or predicted).

1. Personnel activities. Americans expect American-type amenities in personal hygiene and wastewater treatment. These attitudes should be incorporated into the facility design. It is typical for permanent facilities to have flush toilets and running water, although modern waterless or low water options are being considered. It is also desirable from the DA viewpoint to engineer alternatives for simple operation and maintenance.

Designers should use the following figures for sizing the facility for per capita sewage flows: (101) 4-2

Permanent installations - 100 gallons per capita
(residents)
30 gallons per capita (8-hr
shift by a nonresident)

guidance WASTEWATER IMPACT/1 Wastewater Sanitary**SEWAGE CHARACTERISTICS**

	Resident personnel (pounds per capita per day)	Nonresident per- sonnel (pounds per capita for 8-hr shift)
Suspended solids (SS)	0.20	0.10
Biochemical oxygen demand (BOD)	0.20	0.10

However, these numbers usually result in overdesign. Per capita factors for small, remote sites could be quite a bit less and still perform satisfactorily for several reasons. First, the extra wastewater producers are not present. Second, a smaller site shows more impact when water conservation is practiced. Third, actual usage numbers for comparable civilian activities are much less. When water shortages exist and maximum water conservation is practical, far less wastewater is produced. Further design considerations are given in TM 5-814-3.

2. Equipment/vehicle - Amounts are small compared to domestic consumption. See "Wastewater impact, Portawasher."
3. Expansion - If expansion of the DCS site is expected, the ability to handle the increased flow should be incorporated into the design. A safety factor of 1.5 is also used for installations of this size. Garbage grinders should be avoided; these increase sewage characteristics to 65 percent for BOD and 100 percent for SS.

b. Site variables

Major factors in site selection of treatment facilities are: topography; availability of a suitable discharge point; maintenance of reasonable distance from living quarters, working areas, and public use areas; and proposed facilities as reflected by the master plans. Plants of 50,000 gallons per day or less treatment capacity will be not less than 500 feet from the above facilities except when this minimum distance results in unacceptable noise or odor levels. Wastewater treatment ponds, regardless of size, will be not less than one-quarter mile from such facilities. Greater distance may be required when such facilities are located on the leeward side of the treatment plant, in areas subject to prolonged or frequent air stagnation or fog/mist cover, and at elevations lower than the treatment plant toward the occupied area. Exceptions to the 500-foot restriction can be made for cold-climate modular complexes for which the treatment system is a part of the complex. Sewage treatment works will not be within the same module as living quarters. Standard septic tank systems with subsurface drain fields do not fall under the 500-foot restriction. In cases for which special design is provided to control aerosols, gases, and odors, a waiver to reduce

guidance WASTEWATER IMPACT/1 Wastewater Sanitary

the minimum distance may be requested through command channels to HQDA (DAEN-MCE-D) WASH DC 20314 for Army projects and HQ USAF/PREEU WASH DC 20322 for Air Force projects. Distance reductions must not create unacceptable noise levels when plant equipment is in operation. The request must state the special design features that support the waiver, including any pertinent supporting data. Unit processes, plant size, and prevailing wind and climatic conditions must be given. In addition, the elevation differentials in relation to prevailing winds, adjacent facilities, and terrain must be fully described. (101) 2-1

C. Susceptibility to groundwater pollution**Landform categories****1. Wind laid**

Sand dunes - Very high, as liquid pollution can infiltrate quickly to the water table due to a high percolation rate. Therefore, avoid using septic tanks; community sewage systems or cesspools are better.

Loess - Slight. The low water table and good percolation rate make it well suited for decomposing action.

2. Water laid

Flood plains - The often high water table and permeable substances make pollution very important.

Terraces - Low where reasonably thick (7 feet), but clay lenses may cause a perched water table, which can be polluted and seep into the regular water supply.

Deltas (birdsfoot) - The groundwater is so near the surface that anything entering the ground will reach it, so there is high potential.

(Arc) - This type is better drained because of the coarser material, but it will also let pollutants through with ease (high percolation rate). Therefore, it also has a high potential.

(Estuarine) - Similar to birdsfoot, although the material is highly saturated organics rather than thick clay deposits.

3. Alluvium

Alluvial fans - Although the water table is deep, the percolation rate is excessive (often greater than 10 inches per hour), so that pollutants can easily reach and contaminate it. This is critical, since the water supply is limited and is usually obtained from the groundwater.

guidance WASTEWATER IMPACT/1 Wastewater Sanitary

Valley fill - Although the water table is usually deep, the percolation rate is high (6 to 16 inches per hour, but may be as little as 2 inches per hour in clay areas) so that pollutants may easily reach and contaminate it. This is critical, since the water supply is limited and is usually obtained from the groundwater. Since alkaline areas are common, care must be taken not to contaminate the water and change the pH.

Continental alluvium - Fines cause a slow percolation rate, so pollution is unlikely. Groundwater is hard; for some purposes, it should be treated to remove minerals because deposits can ruin a piping system.

4. Freshwater deposits

Lake beds and playas - In wet times when the water table is near the surface, these are very susceptible to pollution. Therefore, they are really unfit for septic tanks for sanitary landfills.

Organic deposits - Swamps act as purifying systems for groundwater so that, although surface water may be impure, the filtration process is important. Filling or clearing will interfere with this process. Also, the high water table makes the cleared areas susceptible to infiltration pollution.

5. Marine

Coastal plains - Overdrawing the groundwater supply may cause the saltwater table to rise and possibly contaminate the water supply.

Beach ridges - The coarse soils have a high percolation rate that permits pollutants to reach the water table before they have had the necessary exposure to decomposition or purification by clay.

Tidal flats - Dredging or driving piles may puncture a membrane separating fresh from brackish water and thus pollute the water table.

6. Metamorphic

Slate - The water table is too close to the surface to be suitable for septic tanks or sanitary landfills.

Shist - Although they drain well, soils often form a hardpan in the B-horizon, causing a seasonal water table rise to about 2 feet from the surface. At this time, the water is very susceptible to pollution. Natural ground or artificial cracks make drainage much better.

guidance WASTEWATER IMPACT/1 Wastewater Sanitary

Gneiss - High, particularly in spring when the water table is high due to water standing perched on the rock or on hardpan only a few feet below the surface of usually well drained soil. Thus, pollutants entering the soil will probably pollute the water before they are decomposed or filtered.

7. Glacial

Till - Seasonally high water table can enhance pollution susceptibility.

End/ground moraines - Usually are of coarse material (particularly in the East), but this material is not well sorted and the drainage is deranged, so the water table is high. Thus, they are susceptible to pollution.

Drumlins - Unlikely. The water table is very low so that pollutants seldom reach it before they are purified and decomposed. However, because of the slow percolation rate, a shallow spring water table can be polluted.

Eskers and kames - Some pollution, as the material is so coarse that pollutants can reach the water table before they are completely decomposed and purified. Also, silt lens will cause perching, which is very susceptible.

Outwash - Relatively high. Areas of high water table with excessively well drained soils are susceptible.

Lake beds - High, as the water table is very high.

Permafrost - Extremely high, as the groundwater is a thin surface and has no way of purifying itself. Solid waste can pollute, as the cold inhibits bacterial degradation.

8. Igneous

Granite - Susceptibility is seasonally high on bedrock and B-horizon hardpan.

Basalt flows - Somewhat susceptible, as the water table is high. However, the soils are silts and clays, which make the percolation rate low.

9. Sedimentary

Sandstone - Some chance of pollution, as clays that purify the water are absent. The water table is usually deep.

Shale - Clays will filter minerals and slow percolation, which protects against pollution, but the high water table (2 to 4 feet below surface) will preclude most septic tanks and definitely sanitary landfills.

guidance WASTEWATER IMPACT/1 Wastewater Sanitary

Limestone (arid) - Slight, as it is deep and well purified.

(Humid) - Very high, particularly by water supply pollution from sanitary landfills. A high water table means high pollution because all the groundwater is interconnected by caverns and joints.

Interbedded - Depends on surface materials. Tilted deposits are most susceptible in their recharge zones (see "Susceptibility to change in water table depth"), but impervious, flat layers may cause an unusually high water table in a normally well drained material.

Coal - Exposure to air and oxidation of ingredients will cause an acid release, which will pollute the water table. Also, exposed earth will begin to weather and release large quantities of minerals into surface water supplies.

Portawasher

USA-CERL is involved in developing systems to help Army Facilities Engineers solve solid waste management problems more efficiently. One aspect of the solid waste management program was to develop a more efficient method for cleaning dumpster containers. AR 420-47 requires dumpster containers to be cleaned regularly to "maintain general sanitary conditions and to prevent nuisances."

After much study of existing cleaning methods, it was decided that a new piece of equipment was needed to clean dumpster containers on site, rather than at a central cleaning location. After field tests and some redesigning, the current Portawasher was built by Industrial and Municipal Engineering Corporation (I.M.E.).

Final prototype design characteristics

The prototype Portawasher's design characteristics are:

1. High-pressure washing - At least 1000 pounds per square inch, but probably no more than 1500 pounds per square inch, are needed to remove grime from the sides of the dumpsters.
2. Hot water - Hot water seems to wash best at 180 to 200°F, removing oily dirt difficult to remove with cold water. Hot water also cleans better than steam because it has more impact pressure, makes it easier for the operator to see what he or she is cleaning, and uses safer, more economical operating temperatures.
3. Clean water storage of 200 gallons - With practice, a dumpster can be cleaned with 10 gallons of water. The operator should clean up to 20 dumpsters per day and should carry a full day's supply of cleaning water.

guidance WASTEWATER IMPACT/1 Wastewater Sanitary

4. Wastewater tank of 300 gallons or larger - The capacity of the wastewater tank should exceed the clean water volume to allow for collected solids and other uses, such as spill cleanups, catch basin cleaning, and chemical toilet and vault latrine pumping.
5. A 30 cubic foot per minute, 15-inch mercury vacuum pump - Water and solids are best removed by a vacuum sludge removal system, the type commonly used for servicing portable latrines.
6. Trailer-mount - Mounting the equipment on a flatbed truck would probably be most convenient, but trailer mounting is more economical and provides mobility without requiring a dedicated vehicle.
7. Self-contained unit - All power requirements must be provided by an internal combustion engine mounted on the trailer. Fuel for the hot water heater can be either gaseous or liquid and could be the same as the engine fuel.

Specifications**Vacuum: I.M.E. Model P.B.-135 Vacuum Pump**

- Air capacity--135 cubic feet per minute
- Built-in valving to change pump from vacuum to pressure
- Obtainable vacuum--27 inches mercury (30-1/2 feet of water)

Pressure washer: Hydro/System Series 1600, Model 4B12, with Cat Model 00333 Triplex Pump

- High pressure--1200 pounds per square inch
- Low flow--4 gallons per minute
- Trigger controlled spray wand
- Chemical feed injector for automatic detergent, disinfectant, or deodorant additions

Power supply: Onan engine

- 2-cylinder
- 24-horsepower
- 12-volt electric start
- Belt drive to both vacuum and pressure washer pumps
- Electric clutch to disengage pressure washer when not in use

Water heater: Hydro/System, Series 1400 Water Heater

- Fired by liquified petroleum gas
- 150°F temperature rise
- Thermostat control
- Automatic shutoff when there is no flow

guidance WASTEWATER IMPACT/1 Wastewater Sanitary**Water tank: I.M.E.**

- Two-compartment water tank
- 200-gallon reservoir for clean water
- 300-gallon storage for vacuumed water and solids
- 30 feet of 3-inch vacuum hose
- Liquid level indicators

All components mounted on a tandem axle trailer built by I.M.E.:

- Dry weight--4920 pounds
- Tongue weight--360 pounds

The Portawasher is a portable, self-contained dumpster cleaning system that is more efficient and cost-effective than the central wash system now used at many Army installations. It can be completely assembled from off-the-shelf items and has relatively minor O&M requirements. An installation may be able to procure a Portawasher(s) using Army Quick Return on Investment Program funds.

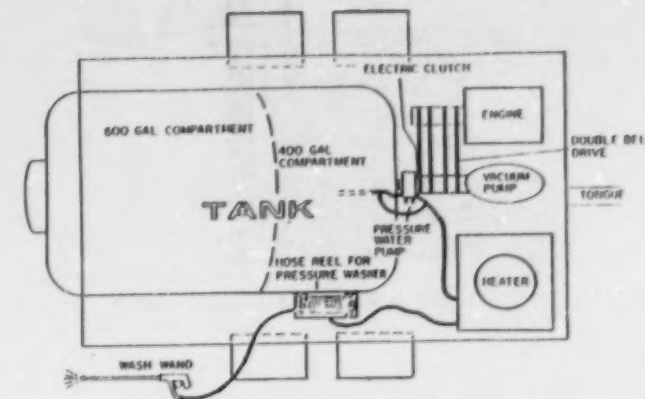
Alternative uses

Although the Portawasher was mainly designed and tested for cleaning refuse dumpsters, it has several other potential uses. It is best suited for the on-site cleaning of containers, structures, and other essentially immovable property, particularly when washwater recovery is important. It is not suitable for cleaning tactical vehicles, but can be used for cleaning administrative-type vehicles and equipment when permanent washing facilities are not available. The vacuum recovery system can be used for servicing portable latrines, for recovering liquid spills, for emptying tanks, or for any operation in which liquid or sludge transfer is involved.

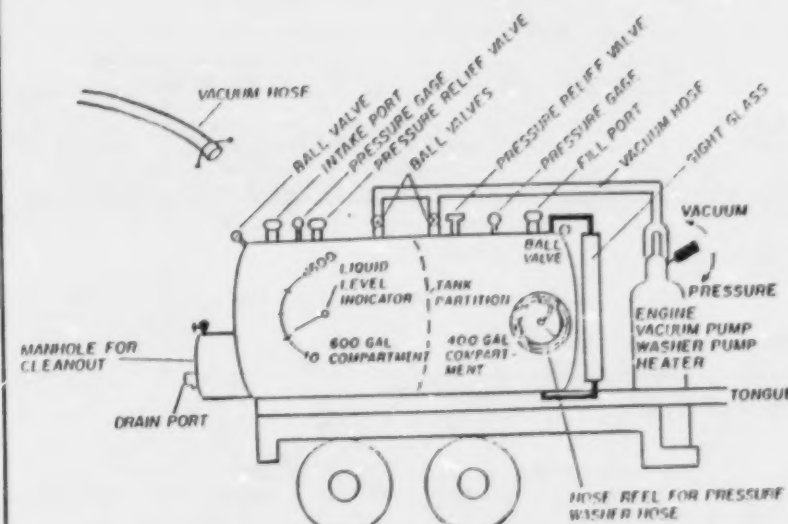
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Champaign, IL 61820
COMM 217-352-6511

guidance WASTEWATER IMPACT/1 Wastewater Sanitary



PORTAWASHER-TOP VIEW.



PORTAWASHER-SIDE VIEW.

guidance WASTEWATER IMPACT/2 Wastewater Treatment

2.a. Treatment regulations and requirements

The design engineer must determine, in advance, the National Pollutant Discharge Elimination System (NPDES) permit requirements for the facility. The NPDES permit can be obtained from the regional EPA office. Because state and local requirements may be even more stringent, the designer should also contact the state pollution control agency. State and local requirements are obviously not identical for every site; thus, the design engineer must obtain firsthand the requirements specific to the plant under design. Following determination of the effluent limitations and other requirements, the engineer must select processes and equipment that will consistently treat the wastewater to the required levels. Since failure to meet effluent limitations may result in enforcement action by EPA, the state agency, or both, the matching of design with permit requirements must not be overlooked or minimized. Furthermore, Federal and State agencies, on occasion, revise effluent standards and water quality standards; therefore, the designer must stay abreast of these changes. While those comments apply directly to U.S. facilities, host nation regulations must be followed for international sites. (100) 2-1

Requirements are contained in AR 200-1 for Army projects and in AFR 19-1 for Air Force projects. These regulations implement Executive Orders and DOD Directives and, in general, direct compliance with treatment requirements established by the Federal EPA and the environmental agency of the state in which the installation is located. The NPDES permit obtained from the local regional EPA office by the installation to which the permit is issued will generally determine the treatment requirements. Effluent requirements for new Federal facilities that establish maximum pollutant discharge limitations will be provided by coordinating the Corps of Engineers Design Office with the EPA Regional Federal Facilities Coordinator. AFP 19-5 provides guidance in coordinating design for Air Force projects, and TM 5-814-8 provides guidance in coordinating design for other military projects. In countries or areas not under U.S. control or administration, projects and activities are subject to the generally applicable environmental laws, regulations, and stipulations of the foreign government concerned. (101) 5-1

Public Law 92-500, with subsequent amendments, requires pretreatment of pollutants that may interfere with the operation of a sewage treatment plant or pass through such a plant untreated. Guidance for coordination with regulatory agencies in the establishment of treatment requirements for waste streams generated at military installations is contained in Section 4 of TM 5-814-8 for Army projects and in AFR 19-1 and AFP 19-5, Chapter 4, for Air Force projects. (101) 3-1

Most states require a minimum of secondary treatment for all domestic wastewaters, and some states require additional removal of phosphorus and nitrogen to prevent eutrophication of water

guidance WASTEWATER IMPACT/2 Wastewater Treatment

bodies. Some states also require maintenance of a specified concentration of dissolved oxygen in the treatment plant effluent. In critical areas, various types of advanced wastewater treatment processes will be imposed by the State regulatory agencies to protect their water resources. The designer must review the applicable State guidelines before setting the treatment level or selecting the treatment process. (101) 3-1

In general, local governments do not specify requirements for wastewater treatment facilities. Construction must conform to applicable zoning and Occupational Safety and Health Administration (OSHA) requirements and to AR 200-1 for Army projects and to AFM 88-15 for Air Force projects. (101) 3-1

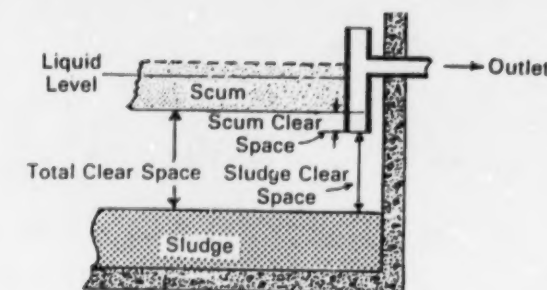
b. Wastewater treatment systems

In designing for expansion of existing treatment works or construction of new facilities, the designer may offer criteria on new treatment processes for consideration. Pollution control facilities will incorporate the latest proven technology in the field. Technology is considered proven when demonstrated successfully by a prototype plant treating similar wastewater under expected climatic conditions. The treatment level obtained and operational performance and maintenance records will have been adequately documented to verify process' ability. Requests for use of such processes, with supporting documentation and service performance record, will be forwarded to HQDA (DAEN-MCE-D) WASH DC 20314 for Army projects and to HQ USAF/PREEU WASH DC 20332 for Air Force projects. (101) 1-2

The requirements for simplicity in O&M must be emphasized, especially in regions where repair parts may be hard to obtain. Wastewater management options include holding tanks with truck hauling, septic tank systems and their variants, direct disposal, and aerobic package plants.

Pit privies are among the earliest methods for direct on-site disposal of human wastes without some sort of preliminary treatment. They can be made portable and moved periodically. Odor control will be possible with ashes or lime layered in. The burnout latrine is another method of human waste disposal which has been used by the Army in very remote areas such as some cold regions.

The most common form of on-site treatment is the conventional septic tank. The main function is as a primary clarifier to separate scum and grease from the wastewater, allowing a more effective final disposal method. The two main methods are the gravity flow type, which is the most common, and the pressure discharge type, which is necessary for mound disposal systems, surface discharges, and connection to pressure sewers.

guidance WASTEWATER IMPACT/2 Wastewater Treatment

SEPTIC TANK SCUM AND SLUDGE CLEAR SPACES. (103) 107

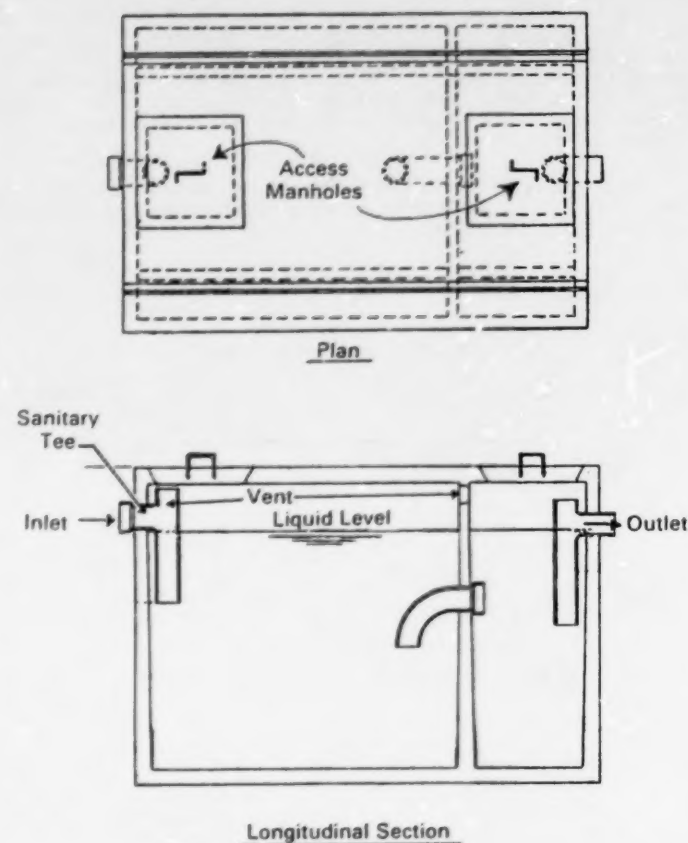
LOCATION OF TOP AND BOTTOM OF OUTLET TEE OR BAFFLE

Total liquid tank (gal) capacity	Tank receiving sewage		Tank receiving sewage and garbage	
	Projection ^a above liquid level	Penetration ^a below liquid level	Projection ^a above liquid level	Penetration ^a below liquid level
500	12	22	--	--
750	12	24	18	38
1,000	12	26	18	41

^aPercentage of liquid depth.

The previous figure is an example of an operating septic tank, with the table indicating some installation and location guidelines.

guidance WASTEWATER IMPACT/2 Wastewater Treatment



TYPICAL TWO-COMPARTMENT SEPTIC TANK. (103) 108

The figure above shows a typical two-compartment septic tank, with the following showing a unit adapted for a larger flow.

guidance WASTEWATER IMPACT/2 Wastewater Treatment

Wastewater treatment, like water treatment at DCS sites, should first examine the possibility of using nearby municipal services. The order of preference should be:

1. Tie-in with municipal or local system of a reliable nature
2. On-site treatment
3. Trucked system

Tie-in with reliable municipal or local system

Building sewer connections are to be underground extending from the nearest sewer trunk that can accommodate the additional load to a point 5 feet from the building below finish grade.

Velocities for sewer system piping shall be computed by Manning's formula, using an "n" value of 0.013 for pipe sizes 12 inches and larger, and 0.014 for pipe sizes 10 inches and smaller. In general, the sewers will be laid on slopes steep enough to provide a velocity of at least 2 feet per second when the pipe is running full and 1.6 feet per second at the average rate of flow. The sanitary sewer from the building shall be able to be sealed completely (air tight) from within the building confines.

On-site treatment

DCS sites, when not connected to a nearby sewage system, will be in the small on-site category. The population usually ranges from 25 or less to 250. Therefore, ample opportunity exists for using many treatment options.

Small plants must make larger safety factor allowances for flow variation and temperature effects relative to total wastewater flows. While able to perform efficiently and effectively, small plants have less flexibility. These plants may consist of wastewater stabilization ponds, trickling filter plants, rotating biological contactors, physical-chemical plants, extended aeration activated sludge plants, and septic tank systems.

At DCS sites, variants of the septic tank system or small package plants will generally be the best choice. The following table presents a selection of disposal methods under various site constraints for septic-type systems. Package treatment plants offer many advantages and should be considered for all feasible uses.

guidance WASTEWATER IMPACT/2 Wastewater Treatment

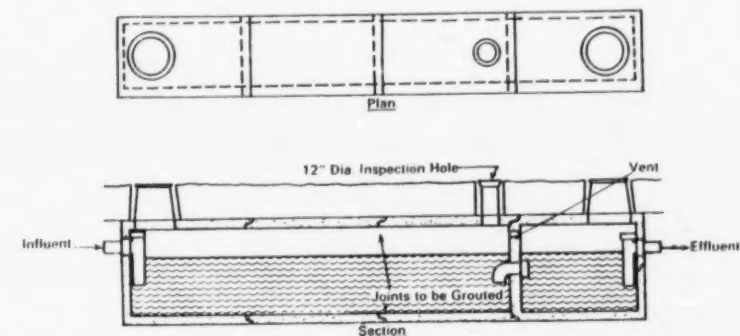
SELECTION OF DISPOSAL METHODS UNDER VARIOUS SITE CONSTRAINTS. (103) 9

Method	Site Constraints											Small Lot Size	
	Soil Permeability			Depth to Bedrock			Depth to Water Table		Slope				
	Very Rapid	Rapid-Moderate	Slow-Very Slow	Shallow and Porous	Shallow and Nonporous	Deep	Shallow	Deep	0-5%	5-15%	15%		
Trenches		X	X ¹			X		X	X	X	X	X	X ²
Beds		X				X		X	X				X
Pits		X				X		X	X	X	X		X
Mounds	X	X	X	X	X	X	X	X	X	X	X		
Fill Systems	X	X ¹	X ¹	X	X	X	X	X	X	X	X	X	X ²
Sand Lined Trenches or Beds	X	X	X ¹			X		X	X	X ¹	X ²		X ²
Artificially Drained Systems		X				X	X		X	X	X ¹		
Evaporation Infiltration Lagoons		X	X ¹			X		X	X				
Evaporation Lagoons (lined) ^{2,5}	X	X	X	X	X	X	X	X	X	X			
ET Beds or Trenches (lined) ^{4,5}	X	X	X	X	X	X	X	X	X	X	X ²		
ETA Beds or Trenches ⁶		X	X			X		X	X	X	X	X	X

¹ Only where surface soil can be stripped to expose sand or sandy loam material.² Construct only during dry soil conditions. Use trench configuration only.³ Trenches only.⁴ Flow reduction suggested.⁵ High Evaporation potential required.⁶ Recommended for south-facing slopes only.

X means system can function effectively with that constraint.

FOUR PRECAST REINFORCED CONCRETE SEPTIC TANKS COMBINED INTO ONE UNIT FOR LARGE FLOW USES. (103) 114

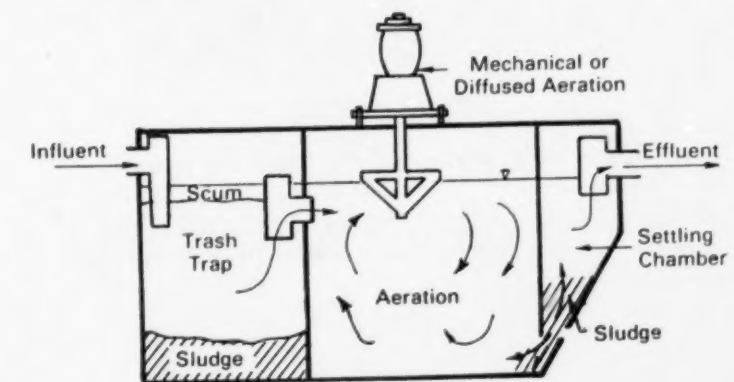
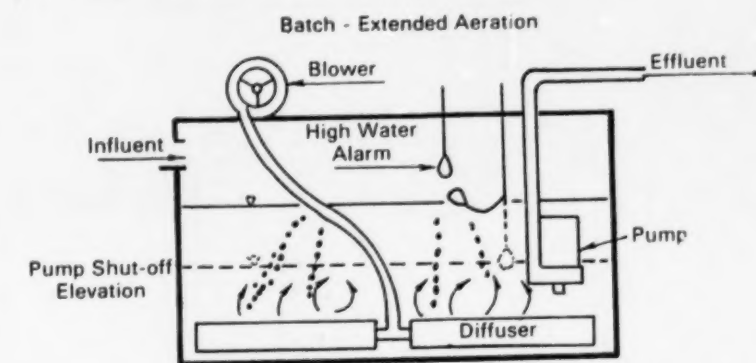


guidance WASTEWATER IMPACT/2 Wastewater Treatment

Septic solids should be pumped out yearly in cold regions and every 3 to 5 years in warmer regions due to anaerobic digestion of the settled sludge. Local regulatory agencies will specify the septic tank volume required. Typically, the tanks are buried, but occasionally they are located above ground on suitable foundations. Also, thermal protection may be required in cold regions.

Tank materials include concrete, steel, plastic and fiberglass. The limitations of each material must be considered and a suitable choice made.

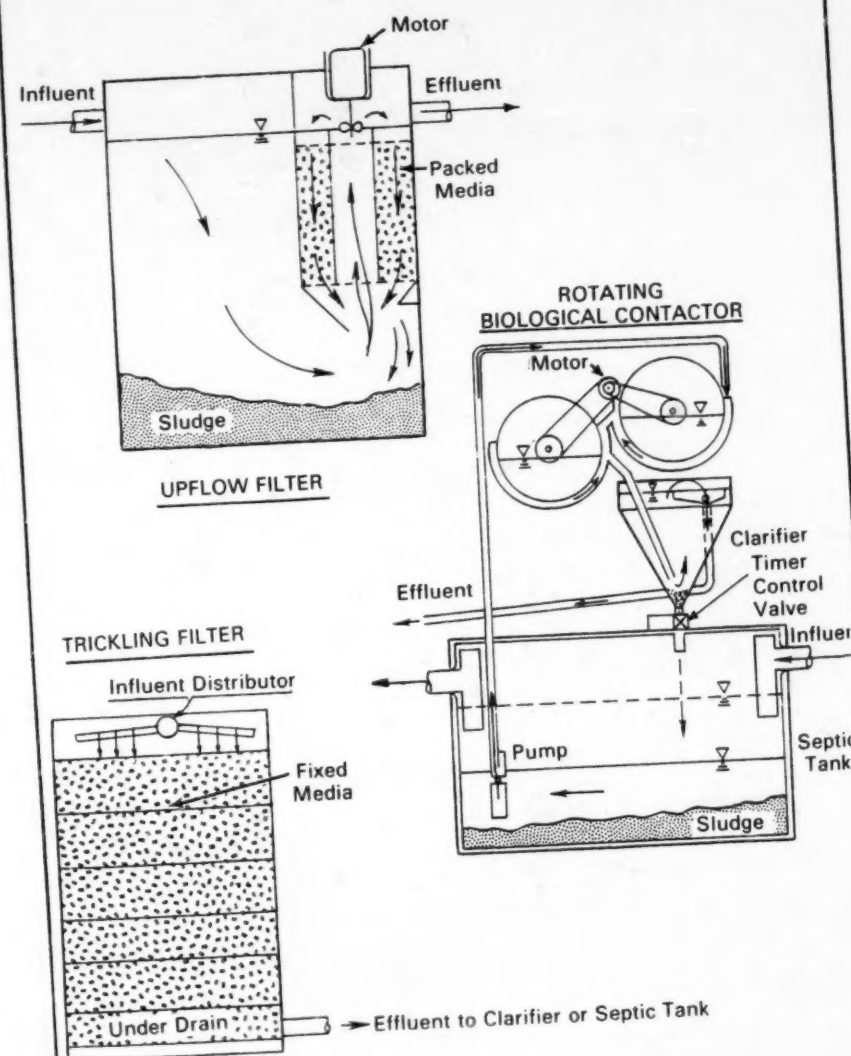
EXAMPLES OF EXTENDED AERATION PACKAGE PLANT CONFIGURATIONS. (103) 144



Flow-Through Extended Aeration

guidance WASTEWATER IMPACT/2 Wastewater Treatment

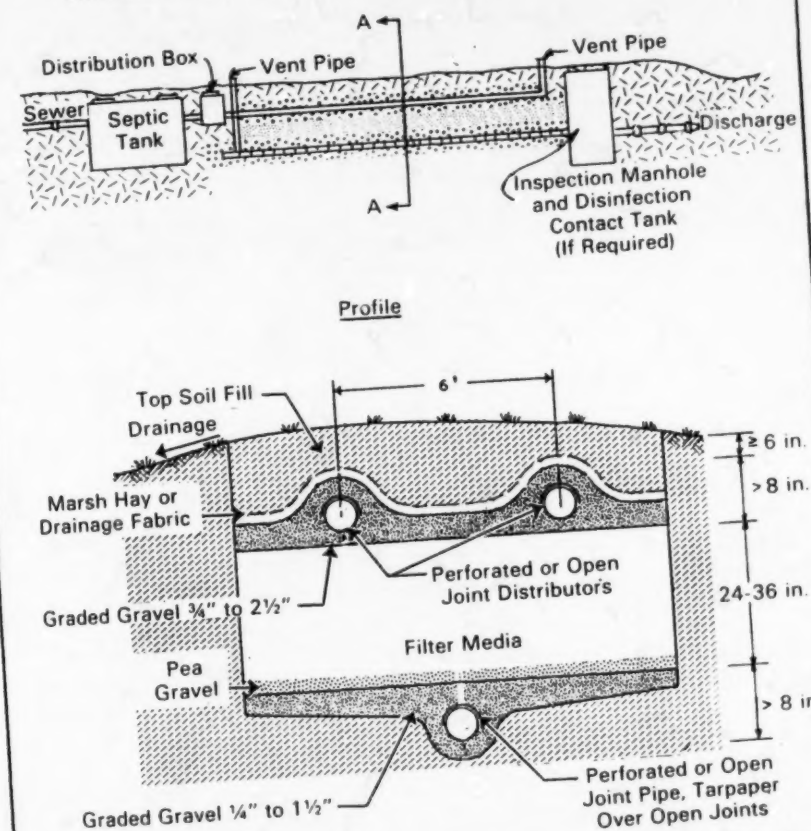
EXAMPLES OF FIXED FILM PACKAGE PLANT CONFIGURATIONS. (103) 156



guidance WASTEWATER IMPACT/2 Wastewater Treatment

On-site aerobic treatment systems include variants of the activated sludge process (usually extended aeration) (see the figure below) and attached growth processes (trickling filters, RBCs, or upflow filters) (see the next figure). A higher quality effluent is usually claimed with its attendant advantages. These units have mechanical elements and require routine maintenance on at least a monthly basis and periodic disposal of accumulated solids. Additionally, a pretreatment step may be needed to remove gross solids. Other concerns are more thermal protection in cold regions and possible septicity in warm regions.

TYPICAL BURIED INTERMITTENT FILTER INSTALLATION. (103) 129



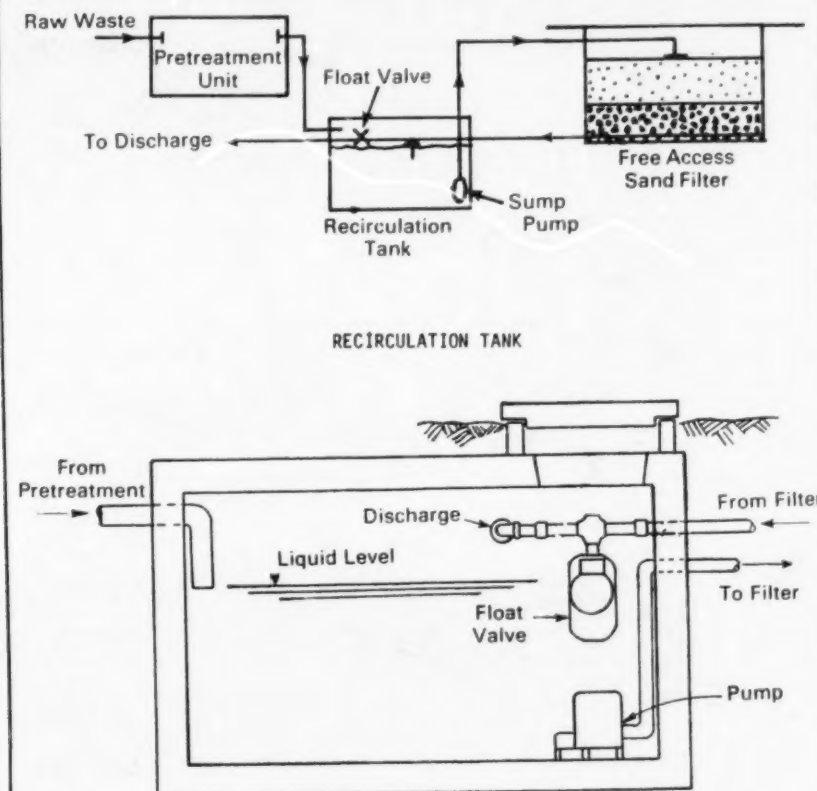
The figure above shows a typical buried intermittent filter installation; the next figure shows a typical free-access intermittent filter.

guidance WASTEWATER IMPACT/2 Wastewater Treatment

Variations in biological activity must be considered during the design phase. For example, equipment should be oversized in cold regions since the activity of the microbes doing the decomposition is temperature-dependent.

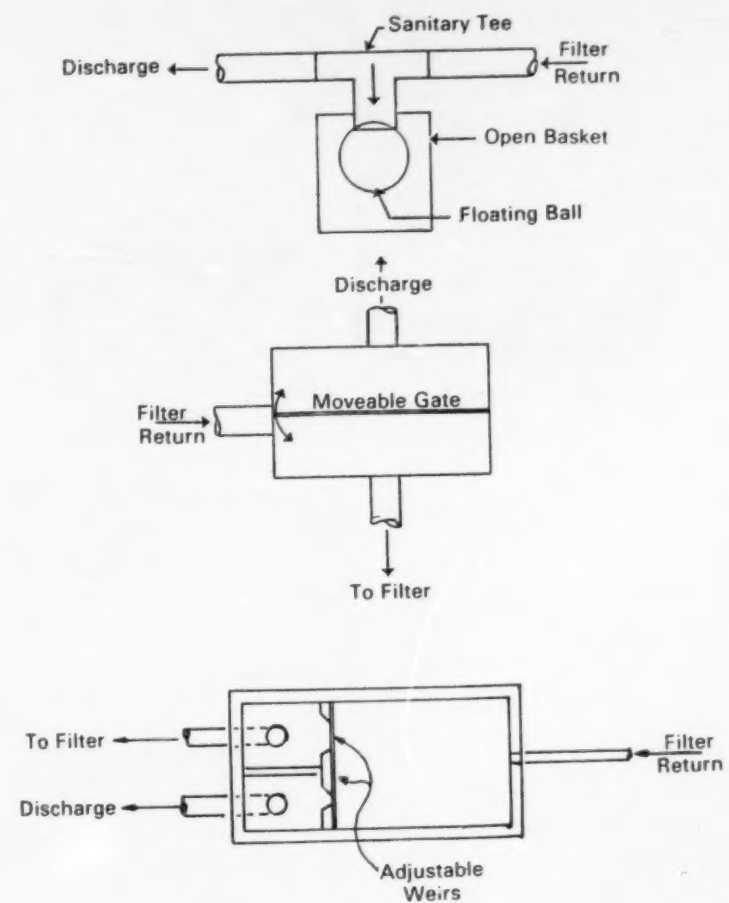
Disposal of the effluent from the package plant or septic tank system is necessary. Direct discharge is permissible at some locations, but usually additional steps are required. In the United States, intermittent sand filtration is commonly used when necessary or desired for surface discharge.

TYPICAL RECIRCULATING INTERMITTENT FILTER SYSTEM. (103) 134



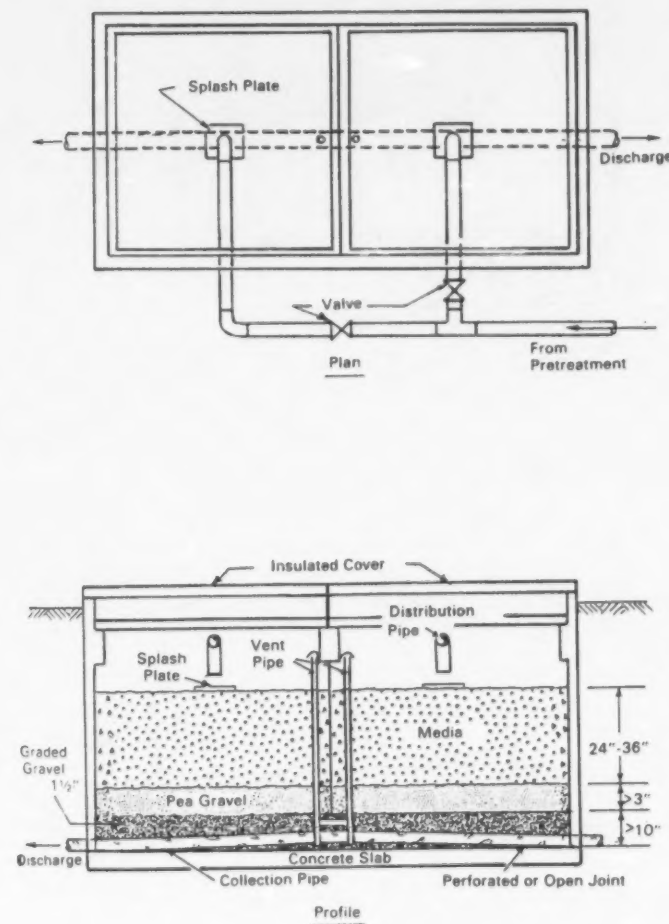
guidance WASTEWATER IMPACT/2 Wastewater Treatment

BYPASS ALTERNATIVES FOR RECIRCULATING FILTERS. (103) 135



guidance WASTEWATER IMPACT/2 Wastewater Treatment

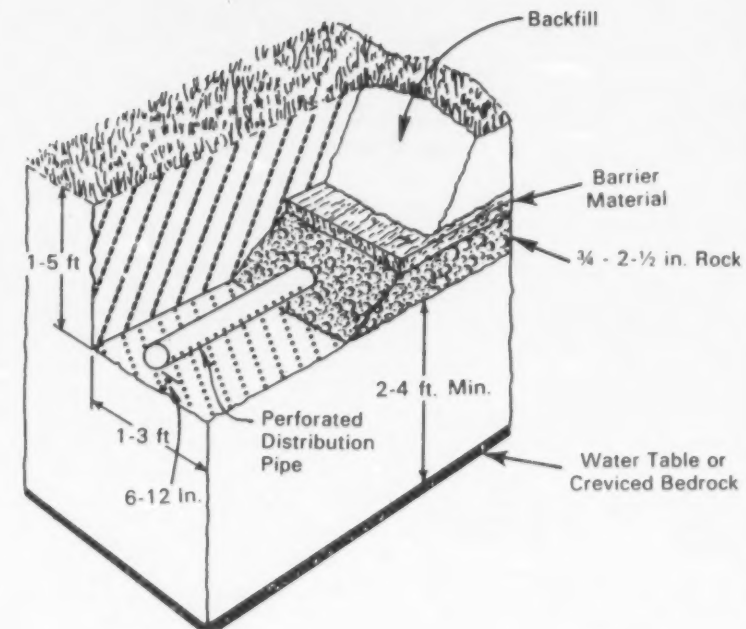
TYPICAL FREE ACCESS INTERMITTENT FILTER. (103) 131



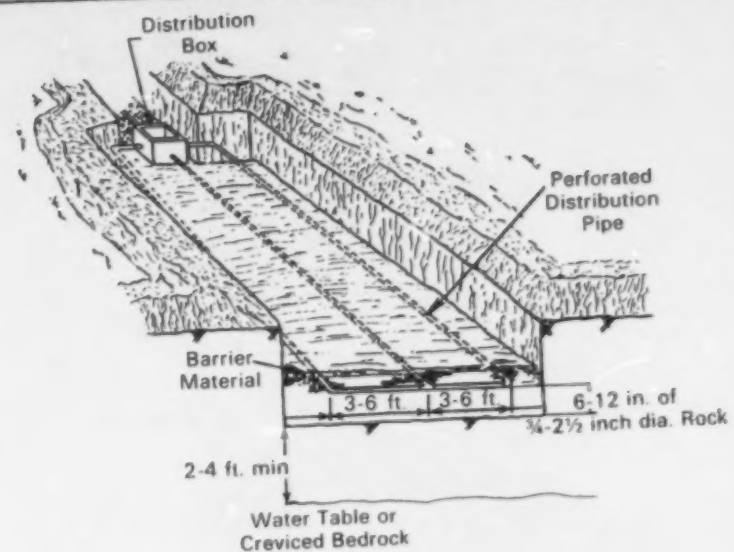
guidance WASTEWATER IMPACT/2 Wastewater Treatment

In-ground disposal through leach fields or seepage pits is the most common technique. Cold regions are more likely to have seepage pits because they are more compact and thermally efficient.

TYPICAL TRENCH SYSTEM. (103) 209



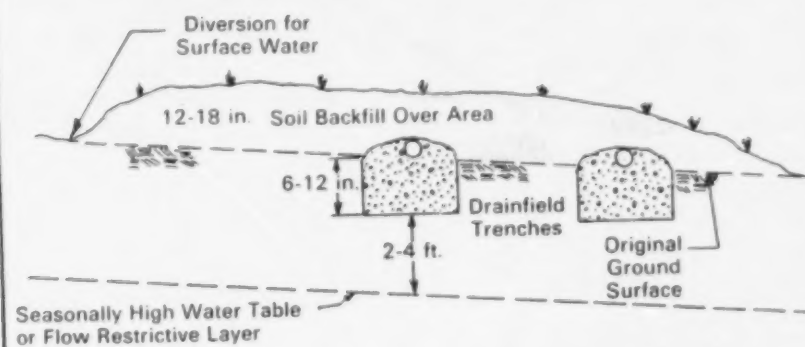
guidance WASTEWATER IMPACT/2 Wastewater Treatment



TYPICAL BED SYSTEM. (103) 210

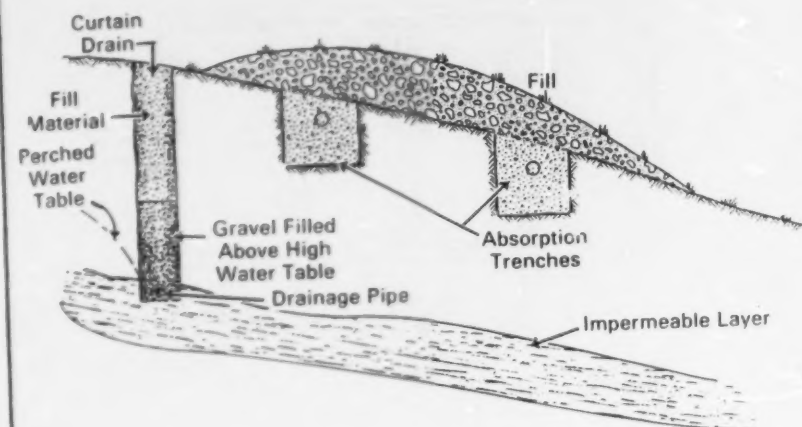
Often, high water tables are present that limit the use of trenches, beds, or seepage pits. These water tables can sometimes be artificially lowered to permit the use of such methods. Soil and site conditions determine which method is selected (see the figures below).

TRENCH SYSTEM INSTALLED TO OVERCOME A SHALLOW WATER TABLE OR RESTRICTIVE LAYER. (103) 222

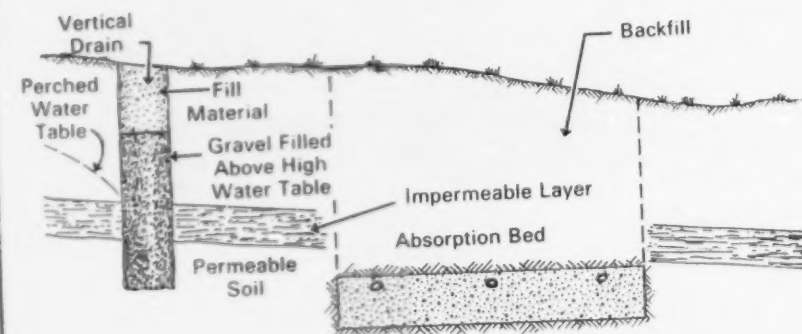


guidance WASTEWATER IMPACT/2 Wastewater Treatment

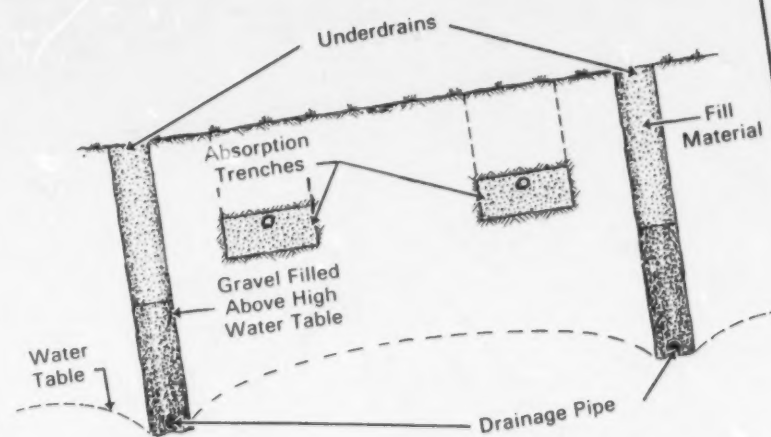
CURTAIN DRAIN TO INTERCEPT LATERALLY MOVING PERCHED WATER TABLE CAUSED BY A SHALLOW, IMPERMEABLE LAYER. (103) 261



VERTICAL DRAIN TO INTERCEPT LATERALLY MOVING PERCHED WATER TABLE CAUSED BY A SHALLOW, THIN, IMPERMEABLE LAYER. (103) 261

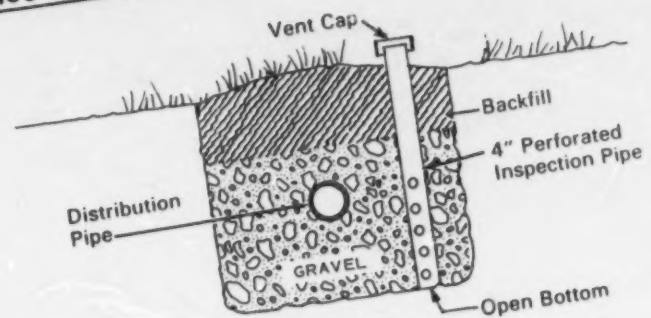


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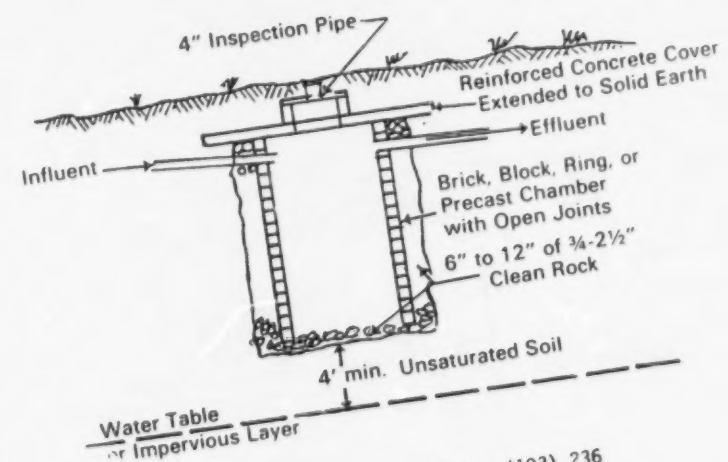
UNDERDRAINS USED TO LOWER WATER TABLE. (103) 262

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TYPICAL INSPECTION PIPE. (103) 228

The filter above shows a typical inspection pipe for judging performance of a leach field.



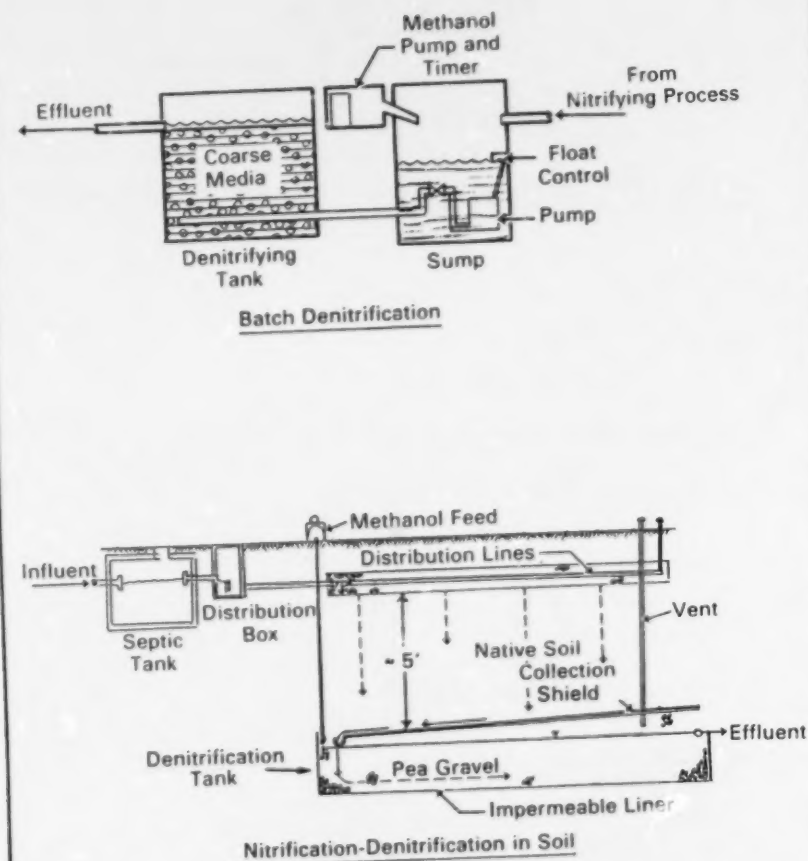
SEEPAGE PIT CROSS SECTION. (103) 236

The figure above shows a typical seepage pit cross section.

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Often, nitrogen in some form is a potential groundwater or surface water contaminant and regulatory agencies may require control. Typical on-site denitrification systems are shown below.

ON-SITE DENITRIFICATION SYSTEMS. (103) 190

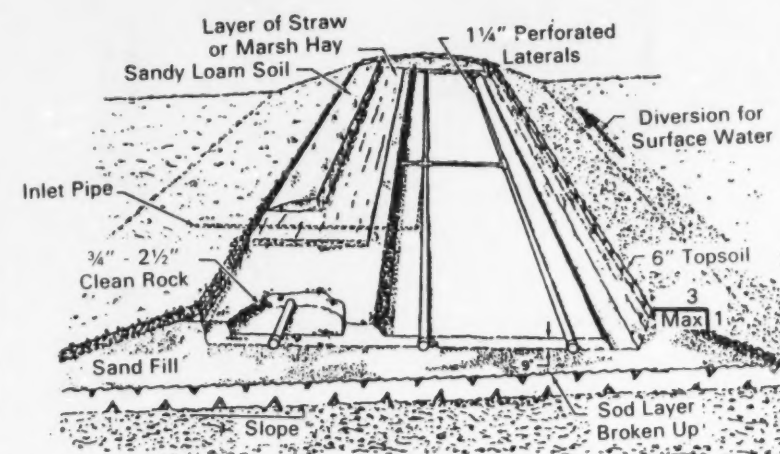


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The required surface area for leach fields is usually based on simple percolation tests. A procedure is available in TM 5-814-3. (101)

Clay soils or sites with high groundwater tables or shallow bedrock may be suitable for use of mound or raised bed disposal systems. The principle is to raise the application bed enough so that the larger base area of the mound serves as the design infiltration surface. The following figures offer more information on mound systems.

DETAILED SCHEMATIC OF A MOUND SYSTEM. (103) 241



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The mound's dimensions depend on the size and shape of the absorption bed, the permeability of the natural soil, the slope of the site, and the depth of fill below the bed. The table below gives depths and dimensions.

The downslope setback (I) in the next figure depends on the natural soil's permeability. The basal area of the mound must be large enough to absorb the wastewater before it reaches the perimeter of the mound or surface seepage will result. On level sites, the entire basal area ($L \times W$) is used to determine I. However, on sloping sites, only the area below and downslope from the absorption bed is considered $[I(B) \times (A + I)]$. (103) 246

DIMENSIONS FOR MOUND SYSTEMS^a (103) 248

Item	Dimension
Mound height	
Fill depth (D) feet	1 (minimum) ^b
Absorption bed depth (F) inches	9 (minimum)
Cap at edge of bed (G) feet	1 ^c
Cap at center of bed (H) feet	1.5 ^c
Mound perimeter	
Downslope setback (I)	Depends on soil permeability
Upslope setback (J) feet	10 ^d
Side slope setback (K) feet	10 ^d
Side slopes	No steeper than 3:1

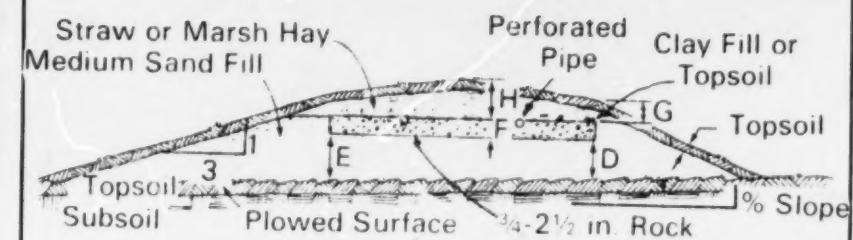
^a Letters refer to lettered dimensions in the above figure.

^b On sloping sites, this depth will increase downslope to maintain a level bed. In shallow soils where groundwater contamination is a concern, the fill depth should be increased to 2 feet.

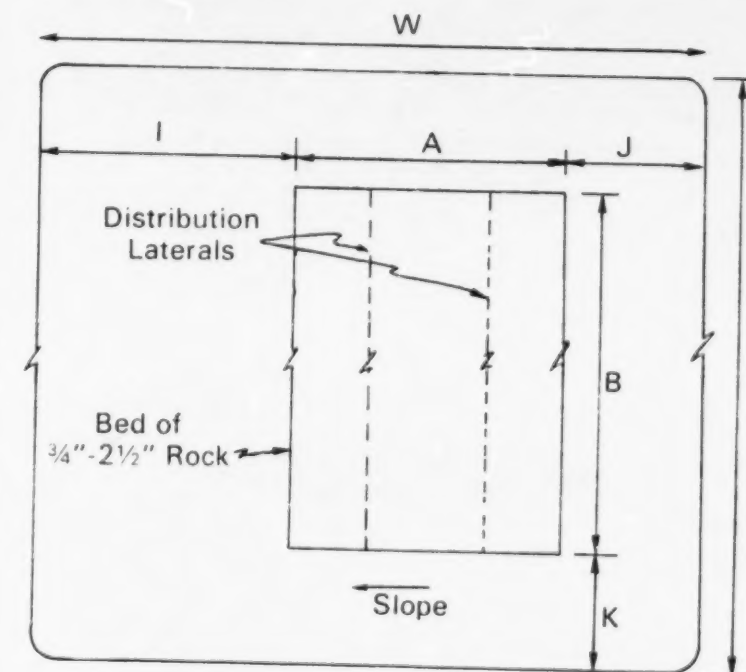
^c A 4- to 6-inch depth of quality topsoil is included. This depth can be decreased by 6 inches in areas with mild winters. If depths less than 1 foot are used, erosion after construction must be avoided so enough soil covers the porous media.

^d Based on 3:1 side slopes. On sloping sites, (J) will be less if 3:1 side slope is maintained.

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(A) Cross Section

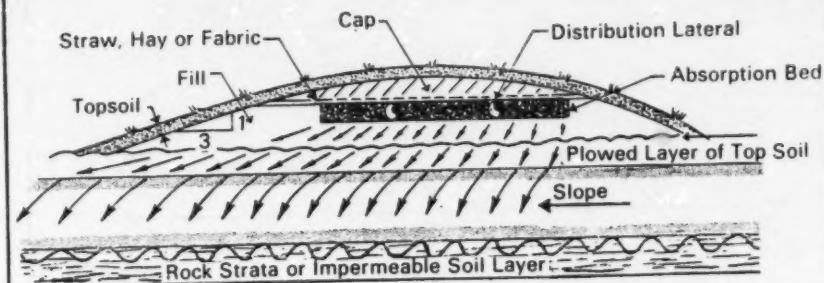


(B) Plan View

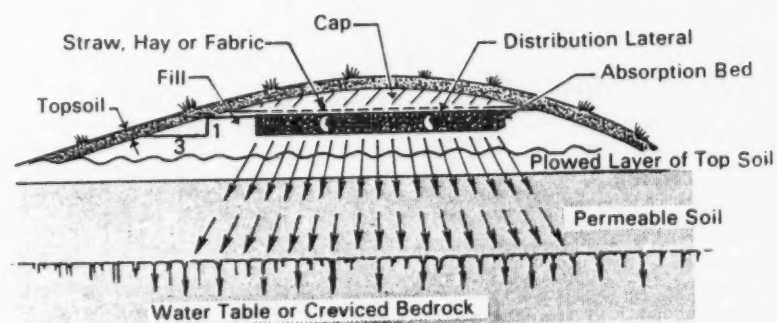
MOUND DIMENSIONS. (103) 247

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TYPICAL MOUND SYSTEMS. (103) 240



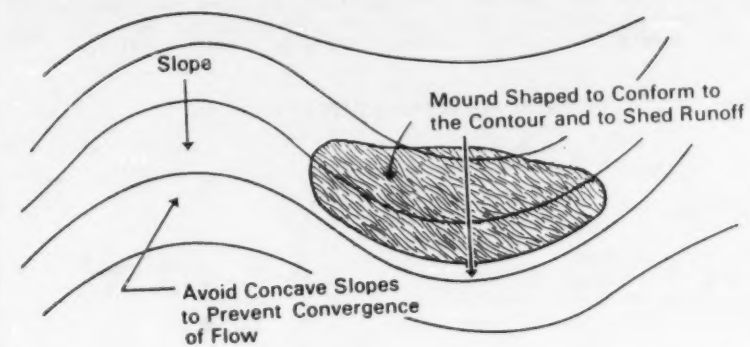
Cross Section of a Mound System for Slowly Permeable Soil on a Sloping Site.



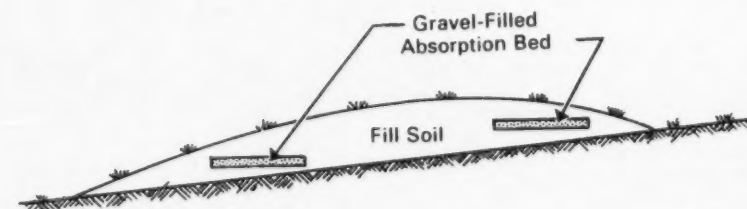
Cross Section of a Mound System for a Permeable Soil, with High Groundwater or Shallow Creviced Bedrock

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PROPER ORIENTATION OF A MOUND SYSTEM ON A COMPLEX SLOPE. (103) 246



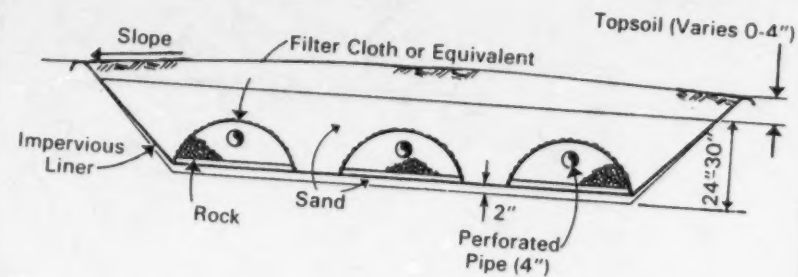
TIERED MOUND SYSTEM. (103), 257



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Evapotranspiration (ET) beds (see the figure below) can be used to discharge wastewater to the atmosphere so that no surface or groundwater discharge is required. This alternative may be suitable in warm, arid climates.

CROSS SECTION OF TYPICAL ET BED. (103) 302

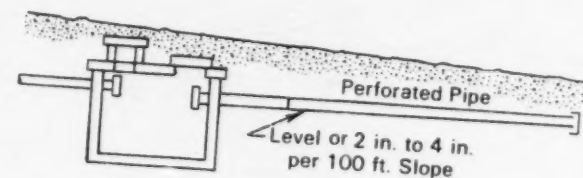
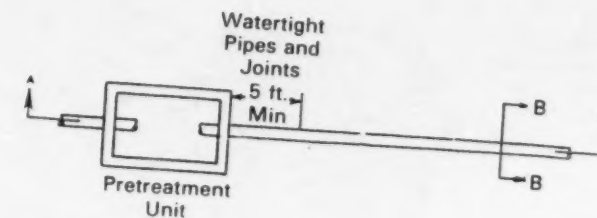


Several different distribution networks are used in subsurface soil absorption systems. They include single-line, closed loop, distribution box, relief line, drop box, and pressure networks. The objective of each is to apply pretreated wastewater over the infiltrative surface.

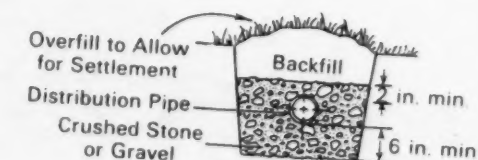
The following nine figures show some networks. Additional information is available in reference 103. Another type of distribution network is the leaching chamber, which uses open bottom chambers that interlock to form an underground cavern. Wastewater is discharged into the cavern through a central weir, trough, or splash plate and allowed to flow over the infiltrative surface in any direction.

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SINGLE-LINE DISTRIBUTION NETWORK. (103) 273



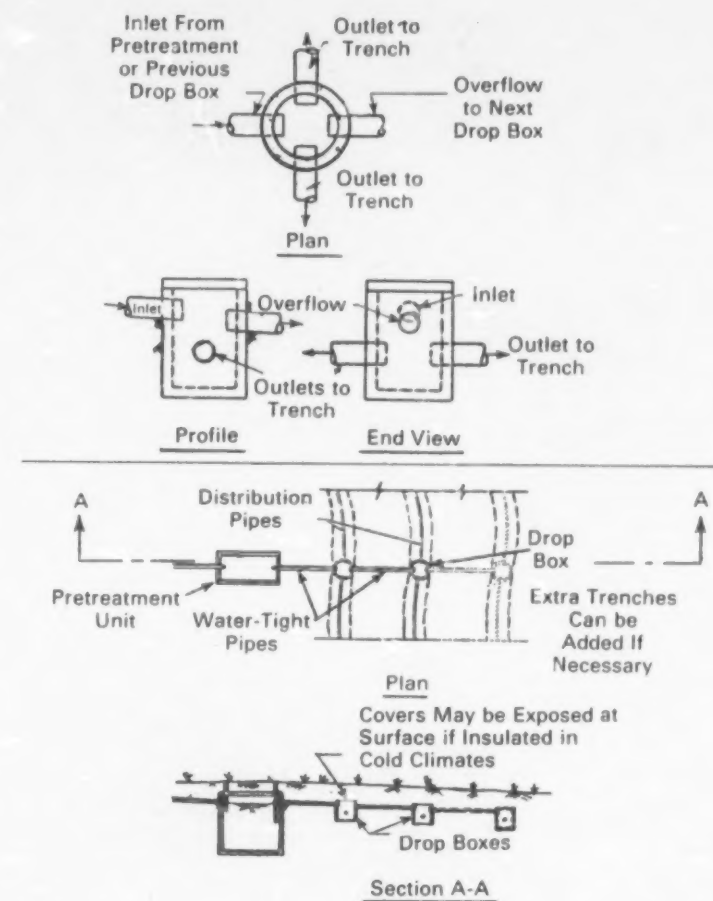
Section A-A



Section B-B

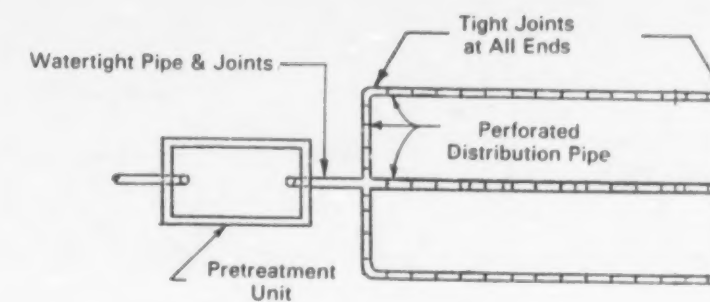
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DROP BOX DISTRIBUTION NETWORK. (103) 274



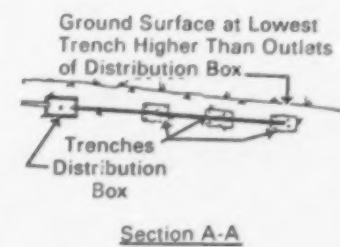
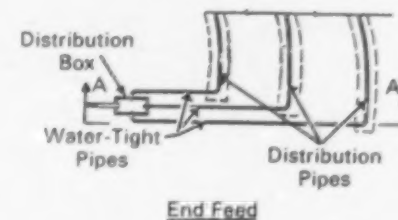
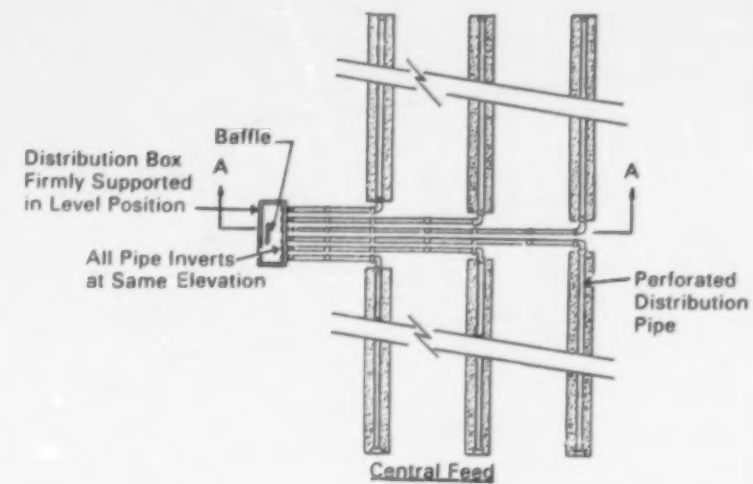
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CLOSED-LOOP DISTRIBUTION NETWORK. (103) 276



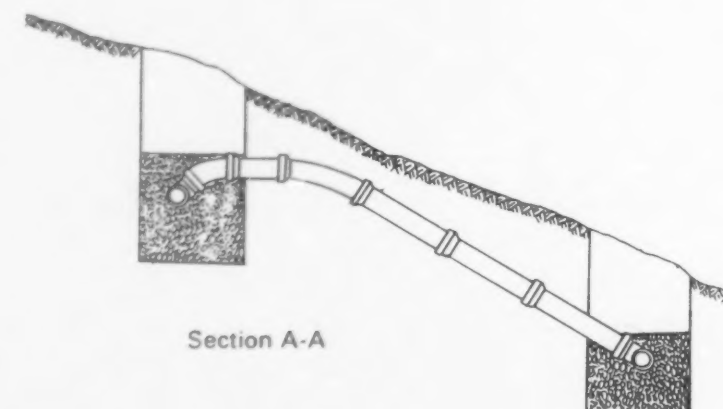
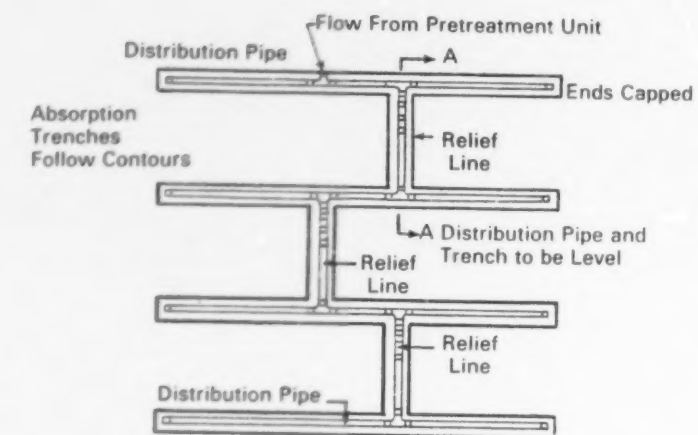
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DISTRIBUTION BOX NETWORK. (103) 277



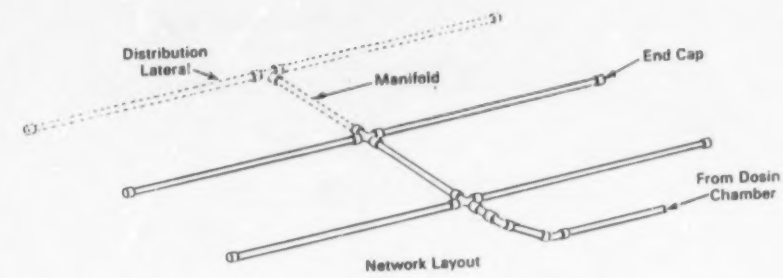
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RELIEF LINE DISTRIBUTION NETWORK. (103) 279



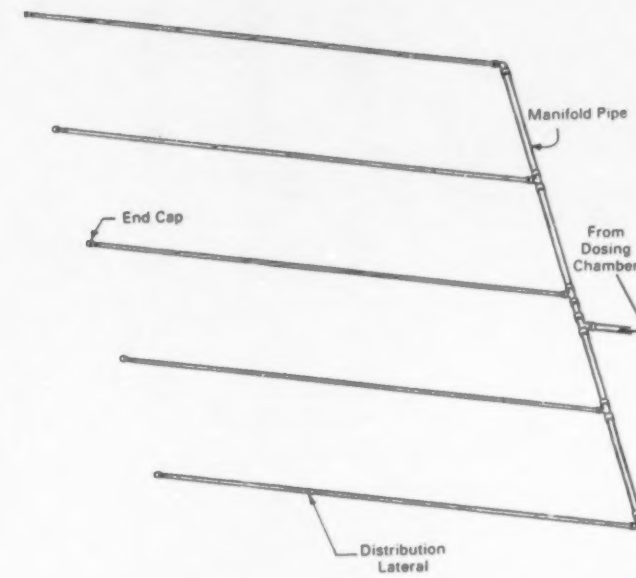
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CENTRAL MANIFOLD DISTRIBUTION NETWORK. (103) 280



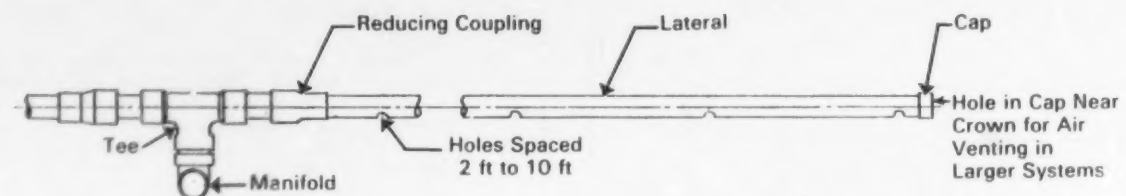
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END MANIFOLD DISTRIBUTION NETWORK. (103) 281

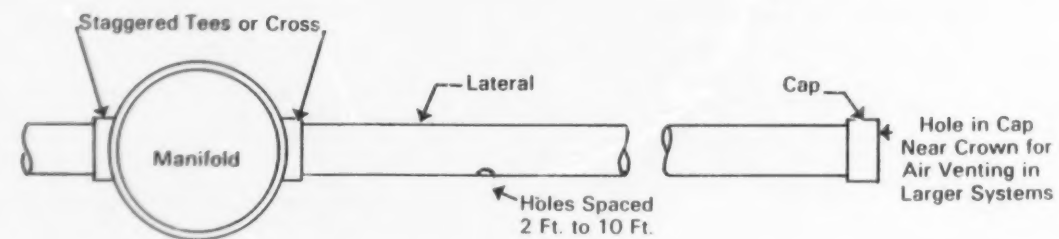


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LATERAL DETAIL--TEE TO TEE CONSTRUCTION. (103) 282



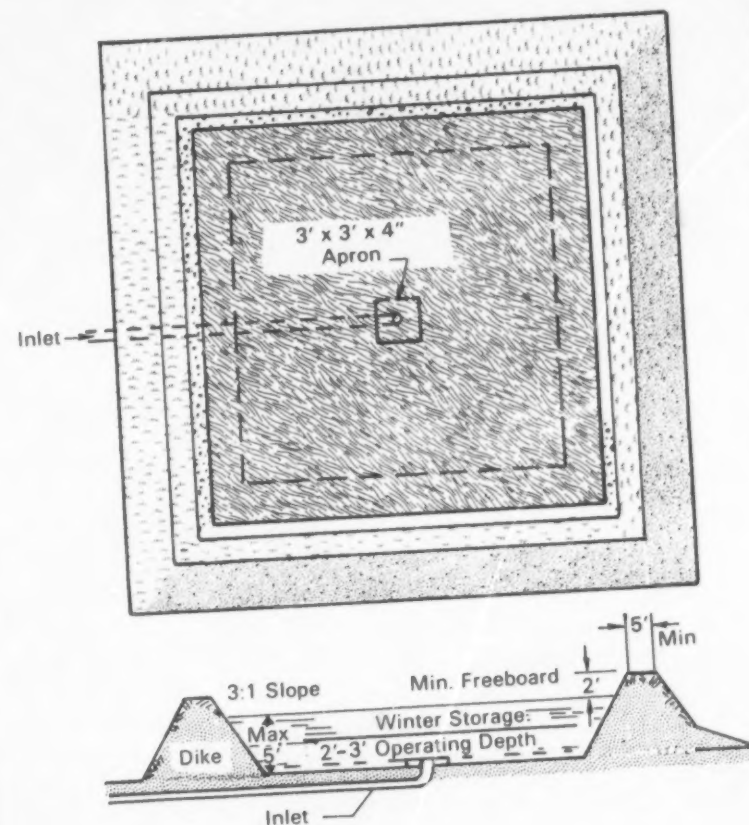
LATERAL DETAIL--STAGGERED TEES OR CROSS CONSTRUCTION. (103) 283



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Lagoons (see the figure below) are another option for wastewater disposal from pretreatment processes such as septic tanks. The wastewater is then evaporated into the atmosphere. Suitable for warm, nonhumid climates, this method must pass through the proper regulatory agencies.

TYPICAL EVAPORATION/INFILTRATION LAGOON FOR SMALL INSTALLATIONS. (103) 312



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Trucked system

Vault toilets are similar in concept to privies, but usually of more permanent construction. Periodic pumping is required and a large manhole is necessary for cleaning.

Holding tanks service facilities that can be equipped with modern plumbing and water saving conveniences. They are emptied periodically by truck or otherwise hauled away for disposal.

C. Site constraints

Several geological and hydrological factors should be considered when designing wastewater treatment plants. Some sites are well drained and gently sloping, so that topography must be carefully considered for maximum use of gravity flow through the entire system. Flat terrain usually requires a decision about pumping the wastewater to some point within the plant before gravity flow can be obtained. (100) 2-3

Geological formations are also of special interest because the designer must know their capacity to support loads. It is also very important to know the absorptive capacity of soils for certain systems. Some wastewater treatment systems may require soils that have a high permeability if they are to function correctly. Examples of these systems are those that use absorption fields or land disposal systems. Dense, fine-grained soils do not function well for these systems. Geological formations may also affect the cost of collection and treatment systems. For example, rock formations may significantly increase excavation costs. (100) 2-3

Lagoons and other wastewater treatment plants using earthen dikes should not be constructed in or immediately over a highly permeable soil. The floors of these structures should be so nearly impervious that an excessive rate of seepage from the basins to the adjacent soil will not occur. In areas where permeable soils are widespread, the design engineer should consider using a liner. To guard against groundwater pollution, the seepage rate should not exceed 0.125 inches per day. Additionally, lagoons should be as far away from populated areas as possible. (100) 2-3

Although rock formations are considered essentially impervious, this may be far from true. Fractured rock and karst-like formations of limestone are not impervious and may permit excessive seepage from the treatment facility. Adequate soil exploration is essential in areas with these known conditions if the designer is to guard against excessive seepage into adjacent formations and, possibly, against structural failure. (100) 2-4

Physical properties of the atmosphere should be evaluated in the planning phase leading to facilities design. Most important are temperature, pressure, air movements, humidity, cloudiness,

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and precipitation. Not only are average conditions important, but so are the extremes and variability of the elements. Generally, it is best to locate these facilities downwind when possible to minimize odor and aerosol problems. This is especially important when treated effluents from facilities are to be treated further by another method. (100) 2-4

d. Conservation options

(See also "Requirements--Conservation devices and system equipment.")

1. Composting toilets

To alleviate human waste management problems at Army remote sites (e.g., firing ranges, guard stations, and training and recreational areas) CERL is investigating alternatives to the pit privies, vault latrines, and chemical toilets currently in use.

Dissatisfactions with current systems include (1) crude construction, insect infestation, and offensive odors; (2) groundwater and soil contamination resulting from improper privy location and vault overflows; (3) creation of potential health hazards; (4) excessive maintenance costs and requirements; and (5) adverse impact on wastewater treatment plants when vault contents are emptied. After a survey of state-of-the-art techniques for remote site waste treatment, two alternatives were chosen as having the most promise for meeting Army needs and requirements--the composting toilet and the aerated vault latrine. Both eliminate odor by breaking down waste aerobically.

Although the composting toilet's first cost is high, subsequent O&M costs are relatively low. The unit requires no water and consumes only the energy needed to operate a small ventilation system for maintaining aerobic conditions. A bulking agent (such as leaves, grass clippings, or sawdust) must be added once or twice a week, but maintenance costs remain low if this task is performed by military personnel. As a result of composting, the volume of waste is reduced by 90 percent. This waste product requires removal only once or twice a year and can be safely handled for disposal purposes.

The aerated vault toilet maintains aerobic conditions by introducing oxygen into the wastes. Installation costs are low when there is an existing vault latrine. Also, maintenance is low because no additives are required and waste volume loss during aerobic breakdown reduces the required frequency of waste removal by 75 percent. In most cases, these cost reductions will pay for the system in 2 years.

At present, most military installations are spending between \$60,000 and \$500,000 annually for remote site waste treatment. Fort Bliss spends \$168,000 per year to maintain

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350 Port-a-pots, and Fort Dix spends \$231,000 per year on its 55 vault latrines and 275 Port-a-pots. USA-CERL estimates that replacing these systems with composting toilets would reduce O&M costs by about 33 percent. Vault aeration is even more cost effective when vault latrines are already on site and power is available. When new facilities are being constructed, however, composting toilets are recommended due to their lower energy and maintenance requirements. They are also ideally suited for very remote areas because solar energy can be used to provide the required power economically.

USA-CERL is currently testing these systems at three installations to determine their suitability for Army use. Part of this testing will include an assessment of potential health hazards to users and maintenance personnel.

USA-CERL-POC is Dr. Ed Smith, COMM 217-352-6511, Ext. 232, FTS 958-7232, or AUTOVON through Chanute AFB.

e. Special waste disposal

Special consideration must be used in extreme environments. For example, permafrost in cold regions may require aboveground utilidors and thermal protection of process equipment in addition to specialized construction practices. Sewage in cold regions will vary from temperate regions by being lower in quantity and higher in organic loading. The total quantity should be close to the amount of water supplied. See also references 102, 104, and 109.

Tropical areas subject to typhoons must have backup power or be connected to typhoon-proof power facilities connected by underground lines.

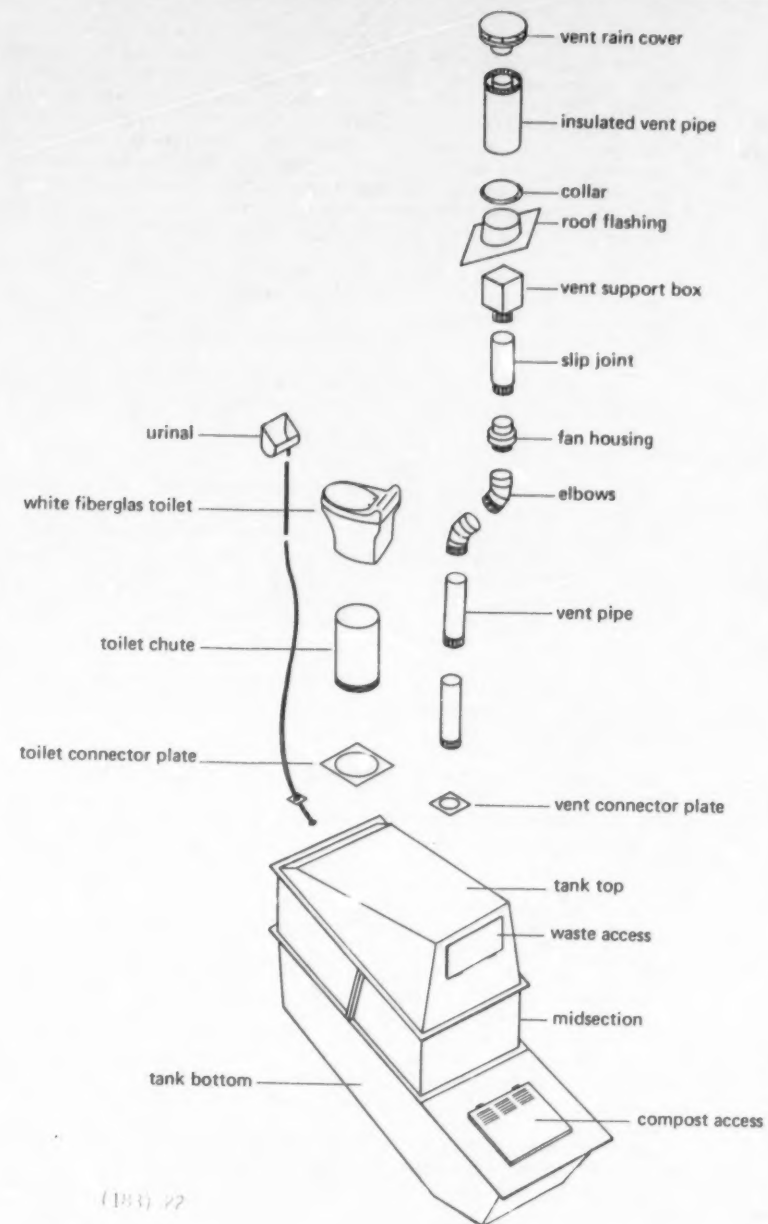
Wastewater treatment in arid and seismic regions (105)

Foul sewage and fouled processes and equipment can be special problems in arid climates. Sewage can reach 35°C, becoming septic much sooner than in temperate zones. Another factor affecting sewage collection is the relatively low per-capita water consumption, which leads to more dense sewage and reduction of scour velocities in collection systems. The resultant septicity in the system produces odor, toxicity, and corrosive activity on equipment and piping. Sewage is likely to be septic on arrival at the treatment facility, requiring special attention.

In wind-blown sand regions, air filters are necessary to protect equipment. In seismic areas, bypass structures should be provided to allow primary treatment in case of preliminary treatment failure. See TM 5-809-10 for construction practices.

For seismic areas, circular basins tend to give greater structural stability than rectangular ones. For ponds, the seismic considerations are negligible, although liners should be used.

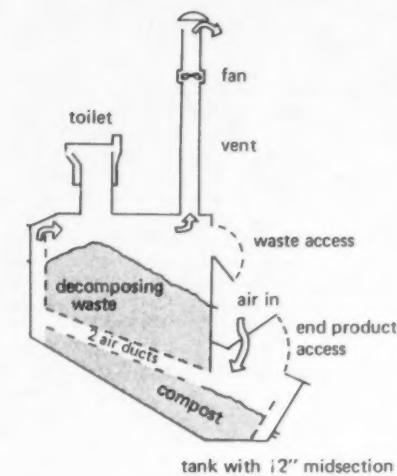
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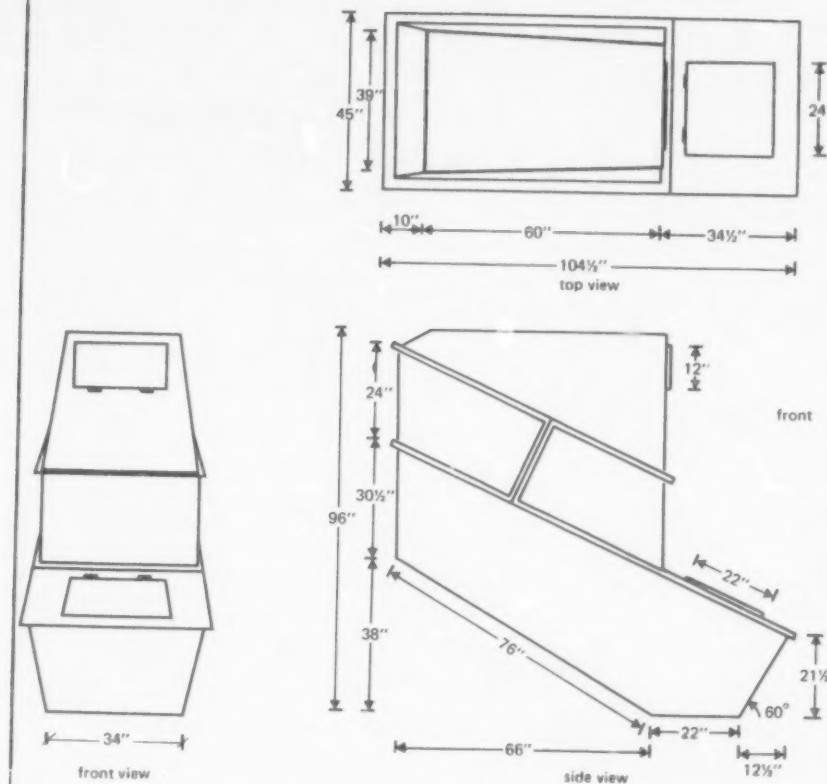
In warm climates, the biological processes will have increased efficiencies along with the potential for an algae control problem with certain wastewater treatment options. Ponds as part of the wastewater system can take very high organic loadings due to a higher metabolism in warm climates.

Small package plants should be well housed in arid regions due to the effects of windblown sand. Proper ventilation is also important when the plant is enclosed.



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(183) 14

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1.a. Elements of occupant comfort

Psychrometrics

The relationship between humidity and dry-bulb temperature is represented graphically on the psychrometric chart (next figure). When diurnal temperature and humidity "loops" are plotted on this chart, a clear picture of the climate emerges, and the chart becomes a tool to help the designer develop climate-specific design strategies.

Computers can be used to plot all 8760 hours of temperature and humidity points for a "typical" year. However, for the designer working by hand, the best source of data is usually published in NOAA's monthly summaries for each weather station. If they are not available, another option is to reconstruct the annual temperature and humidity envelope from NOAA's annual summaries as follows:

- For each month, plot daily maximum temperature with relative humidity at 4 P.M., and daily minimum temperature with relative humidity at 4 A.M.
- Connect these points with a straight line, and extend the line on each end halfway out to the record high and record low temperatures for that month.
- Connect the endpoints of the lines to find the approximate envelope for this climate. (169a) 4.6

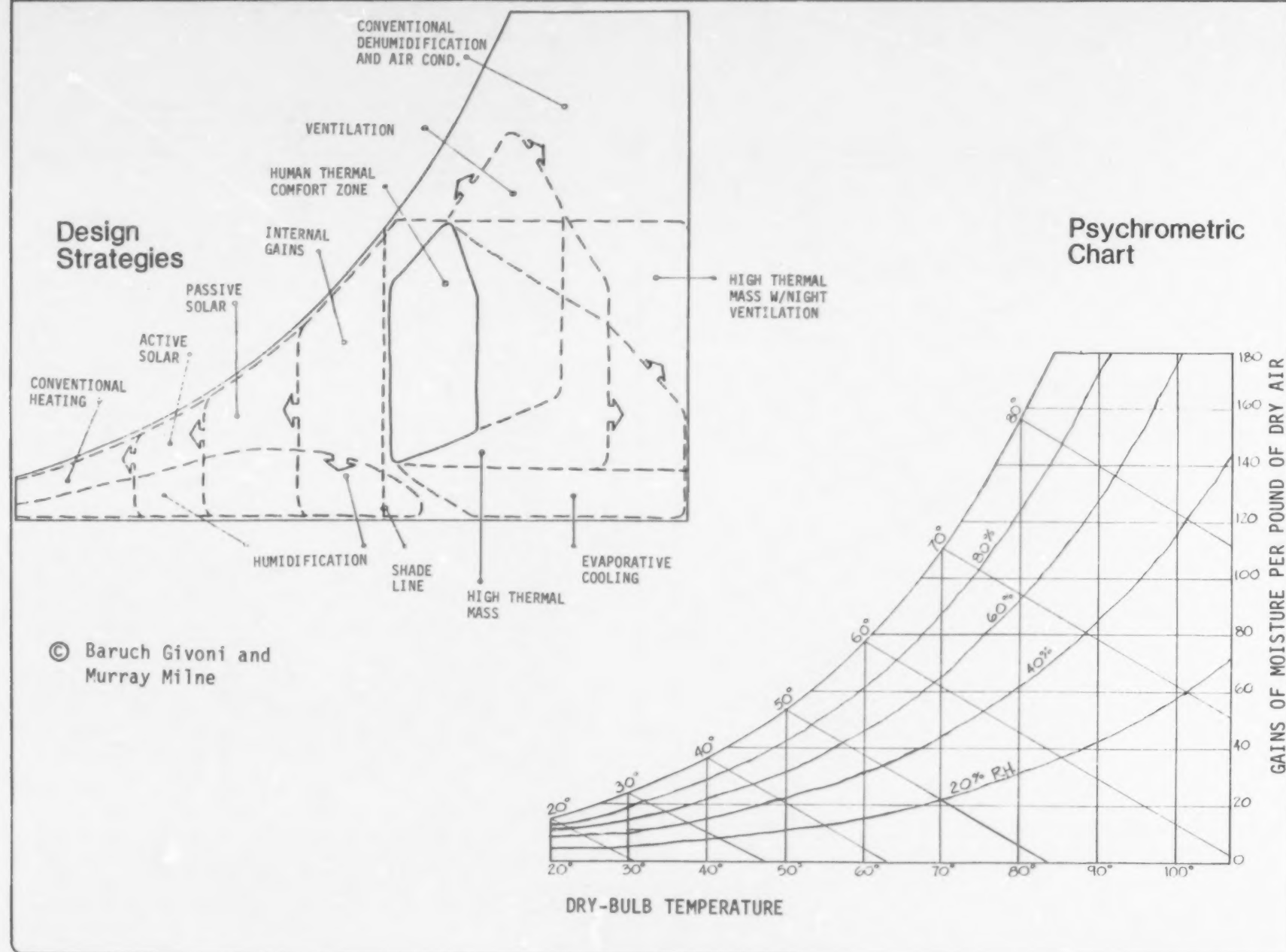
Climatic comfort

The comfort zone may be roughly defined as follows: most people in the temperate zone, sitting indoors in the shade in light clothing, will feel tolerably comfortable at temperature ranges between 70° and 80°F, as long as the relative humidity lies between 20 percent and 50 percent. As humidity increases, these same people will begin to be uncomfortable at lower and lower temperatures, until the relative humidity reaches about 75 percent, when general discomfort at any temperature sets in. But if they are sitting in a draft, the range of tolerable temperature shifts upward, so that temperatures of 85° may be quite comfortable in the 20 to 50 percent humidity range if local air is moving at 200 feet per minute. In the United States, 72°F is considered an "ideal" indoor temperature; in Great Britain 65°F is preferred. (178) 61

Olgay method

On the psychrometric chart, dry bulb temperature is the ordinate and relative humidity is the abscissa. The comfort zone is in the center, with winter and summer ranges indicated separately. The lower boundary of the zone is also the limit above which shading is necessary. At temperatures above the

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comfort level, the wind speed required to restore comfort is shown in relation to humidity. Where ambient conditions are hot and dry, the evaporative cooling necessary for comfort is indicated.

Olgyay's method was the first attempt to systematically incorporate climatic conditions into building design. The system is limited in use, as the analysis of physiological requirements is based on the outdoor climate and not on that expected inside the building in question. The relationship of indoor to outdoor conditions varies widely with different characteristics of the building construction and design. The method is thus suitable for use in humid regions at which ventilation is essential during the day and there is little difference between indoor and outdoor conditions. Using the method in hot, dry areas, particularly in the subtropics, could lead to erroneous conclusions. (177) 309-311

b. Building location, shape, and orientation

The care taken in placing a building on a site with respect to open space and sun is perhaps the single most important decision the designer will make about the building. (179) 73

Buildings blocked from exposure to the low winter sun between the hours of 9:00 A.M. and 3:00 P.M. cannot make direct use of solar energy for heating. During the winter months, approximately 90 percent of the sun's energy output occurs between 9:00 A.M. and 3:00 P.M. sun time. Any surrounding elements that block the sun during these times, such as buildings or tall trees, will severely limit the use of solar energy as a heating source.

To take advantage of the sun in climates where heating is needed during the winter, find the areas on the site that receive the most sun during the hours of maximum solar radiation. Placing the building in the northern part of this sunny area will (1) insure that the outdoor areas placed to the south will have adequate winter sun and (2) help minimize the possibility of shading the building in the future by off-site developments. (179) 74

When deciding on the exact location for the building in a sunny area, give the building a rough shape and place the entrance so that it receives the greatest protection from the cold winter winds. (179) 74

When deciding on the building's rough shape, it is necessary to think about admitting sunlight inside. A building elongated along the east-west axis will expose more surface area to the south during the winter to collect solar radiation. This is also the most efficient shape, in all climates, for minimizing heating requirements in the winter and cooling in the summer. (179) 79

The optimal building shape is one that loses the minimum heat in the winter and gains the minimum heat in the summer. Victor

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Olgyay, in his book *Design with Climate*, has investigated the effect of thermal impacts (sun and air temperature) on building shapes for different climates in the United States. From these investigations he drew the following conclusions:

1. A square building is not the optimal form in any location.
2. All shapes elongated on the north-south axis work both in winter and summer with less efficiency than the square one.
3. The optimal shape lies in every case (all climates) in a form elongated somewhere along the east-west direction. (179) 80-82

Radiation impact on the building sides at different latitudes, both in winter and summer, makes Olgyay's conclusions readily apparent. (179) 82

A building elongated along the east-west axis exposes the longer south side of the building to maximum heat gain during the winter months, while exposing the shorter east and west sides to maximum heat gain in the summer, when the sun is not wanted. In all northern latitudes (32° to 56°F), the south side of the building receives nearly three times as much solar radiation in the winter than the east and west sides of the building. During summer, the situation is reversed and the south side receives much less radiation compared to the roof and east-west sides of the building. Both in summer and winter, the north side of the building receives very little radiation. Besides being an efficiency shape, the large southern exposure is ideal for collecting solar radiation. Major collecting areas (glazing) of the building oriented to the south will intercept the maximum amount of solar radiation available during the winter months. (179) 82-83

At all latitudes, although buildings elongated along the east-west axis are the most efficient, the amount of elongation depends on the climate. Some general principles can be stated for different climates. In cool and hot-dry climates, a compact building form exposing a minimum of surface area to a harsh environment is desirable. In temperate climates, the building shape can be more flexible without severe penalty (excessive heat gain or loss). In hot-humid climates, buildings should be freely elongated in the east-west direction. Because of intense summer solar radiation on the east and west sides in this climate, buildings shaped along the north-south axis pay a severe penalty in energy consumption for cooling. (179) 83-84

Assuming a building elongated along the east-west axis is compatible with other site and design considerations, give the building a rough form by determining its width. When the primary source of sunlight entering a space is through south-facing windows, the depth of spaces along the building's south wall

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should not exceed two and one-half times the height of the windows from the floor. This insures that sunlight will penetrate the entire space. (179) 84

This rule of thumb also provides for adequate daylighting of interior spaces. According to studies by the Illuminating Engineering Society, the depth of a space for adequate natural illumination should be limited to the range of two to two and one-half times the window height (from the floor to the top of the window). For an average window height of 7 feet, this means a maximum space depth of 14 to 18 feet. (179) 84

If the building's major spaces are placed along the south wall (for sunlight requirements) and the buffer spaces are placed along the north wall, the maximum building depth will be roughly 25 to 30 feet. Spaces that need to be deeper or that should not have large, south-facing windows with direct sun shining through can let the sun in through south-facing clerestory windows or skylights. Admitting most of sunlight into a space through the roof has the advantage of allowing flexibility in distributing light and heat to different parts of a space. (179) 84

C. Wind impact

Shelterbelts and windbreaks are most effective when placed perpendicular to prevailing winds. Wind velocity can be reduced to 50 percent for a distance of 10 to 20 times the tree height downwind of a shelterbelt, with the degree of protection and wind reduction depending on the height, wind, length, and penetrability of the plants used. (170) 39

Wind speed is also affected in or on the windward side of a windbreak. The wind speed is reduced for a distance of 300 feet on the windward or front side of a 30-foot-high shelterbelt, for example, and is reduced for a distance of 900 feet downwind or behind the shelterbelt. (170) 39

The zone of wind reduction on the leeward and windward sides of a barrier depends largely on the barrier height. The taller the trees, the more rows are required for protection, because taller trees create more open shelterbelts. Instead of reducing the wind, avenues of trees open at the trunks can increase wind speed as the air stream is forced beneath the tree canopy. (170) 39

The frequency wind occurrence from each direction can be represented graphically, making it easy to identify the most likely wind directions ([169a] 4.10). "Wind roses" combine all three types of data on one diagram: direction, speed, and frequency. They give a quick overview of the significant directions and most likely velocities. To be safe, separate wind roses should be drawn for each different season. NOAA does not publish wind data in a graphic format and does not summarize the raw data in a way that makes it easy to plot by hand. (169a) 4.10

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To provide ventilation, wind speeds must be at least 5 miles per hour. However, low-speed breezes can be boosted to usable velocities through building design. (169a) 4.10

PERCENTAGE WIND SPEED REDUCTION

Belt Density	Avg over First 50 Yd	Avg over First 100 Yd	Avg over First 150 Yd	Avg over First 300 Yd
Very open	18	24	25	18
Open	54	46	37	20
Medium	60	56	48	28
Dense	66	55	44	25
Very dense	66	48	37	20

Reduction in wind speed due to density. (169b) 4.10

Because of its heat transport rate, wind speed has a marked effect on cooling. For example, a 30-mile-per-hour wind with air at 30°F has six times the cooling effect of still air at 10°F. (178) 66

Trees can reduce wind velocity for an area extending 30 to 40 times the height of the trees leeward of the windbreak; the sharpest reduction in wind velocity extends from 10 to 15 times the height of the trees. Maximum shelter from the wind occurs at three to five times the tree height on the leeward side. The deeper the windbreak, the less penetrable it is. Depth has a negligible influence on reducing wind velocity at its leeward edge, but causes notable variation in the microclimate within the sheltered area. In a forest, for example, wind velocity is most reduced within the forest itself. (170) 39

An irregular windbreak that looks like the top of a picket fence is more effective than a uniform one in breaking up the airstream deflected over it. A mixture of plant species and sizes gives the windbreak a rough upper surface more effective in controlling wind. (170) 40

The most efficient ratio of height to length for windbreaks is 1:11.5. This ratio produces the greatest possible shelter effect, at least near the center of the shelterbelt. A current sweeping around shelterbelts increases wind velocity, creating speeds at both ends of windbreaks that are higher than those in an open field. (170) 40

Frequent gaps in a shelterbelt can greatly increase wind velocity in the gap, but this draft does not extend laterally or affect wind abatement at a distance from the gap. (170) 40

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The more penetrable the windbreak, the longer the protected distance behind it. Laboratory tests have shown that when a windbreak is completely impenetrable, practically the entire wind force is deflected upward, over the barrier. Pressure behind the barrier is low because the wind does not pass through, causing a suction effect and forcing the air currents above the windbreaks downward. Shelterbelts with a cross section resembling a pitched roof are less effective in blocking winds than are those with vertical edges. (170) 40

Coniferous trees that branch to the ground are the most effective plants for year-round wind control. Deciduous trees are most effective for summer wind control. Wind velocity directly leeward of a dense spruce planting will be reduced 15 to 25 percent, and a loose barrier of lombardy poplars will reduce velocity by 40 percent. Twelve mile per hour winds will be reduced to 3 miles per hour for a distance of 40 feet leeward of a 20-foot Austrian pine. In landscaping to enhance wind control, the designer should consider the shape, growth rate, and hardness of trees selected. (170) 40

Prevailing winds may change direction seasonally; therefore, plants should be of the type best suited for controlling winds from all directions. A dense coniferous windbreak on the northwest side of a structure, for instance, can protect it from harsh winter winds and direct summer breezes around it. Wind can be slowed or deflected to preserve warmth. It can also be accelerated and channeled through windbreak openings. The angle of the planing will control wind direction in reducing both interior heating and cooling. (170) 40

d. Solar impact

In general, every site's relationship to the sun is dictated by that site's latitude. Sun path charts for most latitudes are available from many sources.

Mean daily solar radiation per month indicates the average daily totals of direct and diffused radiation received in a given location on a horizontal surface during the month. (172) 10

This type of map should only be used to gain a general idea of the available amounts of solar radiation.

Sun

The sun affects a building and its site in two separate ways: the energy incident on the site and its "motion" across the site. (169a) 4.6

Solar radiation

Solar radiation or "insolation" consists of three different components: direct radiation from the sun; diffuse radiation from

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the skyvault (due to atmospheric scattering of direct sunlight), and reflected radiation from the ground and nearby buildings. (169a) 4.6

Solar radiation reaches the outer atmosphere with an intensity of 429 British thermal units per square foot per hour (known as the solar constant). The easiest way to picture the intensity of direct solar radiation is to imagine the number of atmospheres it must cross. (169a) 4.6

When the sun is dead overhead, the incoming radiation passes through the fewest possible thicknesses of atmosphere, which nevertheless reduce its intensity. At 30 degrees altitude, solar radiation must pass through the thickness of two atmospheres, which doubles the reduction. At 19 degrees altitude, incoming radiation is passing through three atmospheres and is reduced three times as much. The presence of dust or cloud cover also contributes to local atmospheric extinction. (169a) 4.6

Solar geometry

One of the most useful design tools is an intuitive understanding of solar geometry. The key to being able to predict the sun's position in the sky over a site is to recall that the earth's axis is tipped at 23 degrees, 27 minutes in its plate of rotation around the sun. Remembering this makes it easy to calculate the sun's noon altitude angle at the summer and winter solstices (June 21 and December 21) and at the equinox (March 21 and September 21). (169a) 4.7

Noon altitude angle is equal to 90 percent latitude plus or minus declination. Knowing the noon altitude angles, for example, becomes useful when designing window sun controls. Assume you want to keep the sun off the window from spring equinox to autumn equinox, and to have the window exposed to full sun on the winter solstice. (169a) 4.7

Solar heat gain

The amount of solar radiation actually reaching a space as heat is a result of three main factors:

- Available insolation (both direct and diffused sunlight)
- Exposed area in each orientation
- Transmission from the surface into the space

Available insolation is a given for each building site, but the designer can control area and transmission to increase or retard the effects of solar radiation. (175) 4

The amount of energy needed to maintain a desirable interior environment depends greatly on variations in the uncontrollable

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exterior environment. Two types of environmental information are used in this energy analysis: (175) 7

- Exterior temperature
- Insolation (direct and diffuse sunlight).

Building orientation affects the indoor climate in two respects by regulating the influence of two distinct climatic factors: (177) 212

- Solar radiation and its heating effect on walls and rooms facing different directions
- Ventilation problems associated with the relationship between prevailing wind directions and building orientation.

Effect of surface orientation on intensity of incident solar radiation

The amounts of solar radiation falling on the different surfaces of a building vary greatly. The figure below shows graphically the variations in solar radiation intensity on vertical surfaces orientated toward the eight semicardinal directions, and on a horizontal surface, as well as on a surface that always faces the sun. This particular example was computed for 32 degrees north latitude; other latitudes will show slightly different patterns. (177) 210

This example shows that a southern wall receives much more radiation in December than in June. Southeastern and southwestern walls also receive more radiation in the winter, but the annual variations are smaller than for southern surfaces. At this latitude, the time of maximum intensity on southeastern and southwestern walls shifts by about 1 hour closer to noon in the summer. The radiation on western and eastern walls is approximately constant, regardless of season. The northern wall receives direct radiation only between March 21 and September 23, during the early morning and late afternoon hours. Horizontal surfaces (roofs) receive the highest solar radiation in summer, but between November and January they receive less than the south wall and even less than southeast or southwest walls. It should be noted that a roof receives no reflected radiation unless it is close to high ground or to a taller structure. (177) 210

Deciduous trees are the most responsive type of shade, providing maximum shade during the height of summer, then obligingly dropping their leaves when maximum insolation is needed during the cold winter months. Plants are also extremely effective in shading windows from extremely low-altitude sun. For example, dense, heavily leafed upright materials planted a distance from a west facing window not only provide a delightful view but also control late afternoon heat loads. Of course, free standing architectural elements can do the same. Siting buildings

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to mutually shade each other is a strategy long used by urban designers and in part explains why residential streets inevitably run east and west in cities with warm climates (such as midwestern United States). However, in colder or more overcast regions (such as the British Isles), "Sun Rights" laws have been written prohibiting a building from excessively shading its neighbors. (177) 210

Shading device design (180) 79-81

Define the times when shading is needed. Data should be collected for the daily temperature changes throughout a year at the place in question. Average daily temperatures should be used with hourly or 2-hourly data for each month of the year. Temperatures that fall over the bottom line of the comfort zone (70°F in the temperate zone, and rising as the latitude decreases) will define the overheated period. This can be tabulated on a chart for which hourly and monthly divisions serve as ordinates.

Determine the position of the sun when shading is needed. On a sun path diagram, the curved lines represent the sun's movements for the dates shown. Lines "radiating" from the North Pole indicate the hours; the light lines show 20-minute intervals. The sun's position is usually expressed by altitude, or angular distance above the horizon, and azimuth, or angular distance measured along the horizon in a clockwise direction. When the overheated period is transferred to this chart, the resulting sun-path diagram will not only show the sun's position, but will indicate whether shading is desirable at a given time.

By the nature of the diagram, each line represents two dates when the sun has the same path during a year. The plotted overheated period will have areas (indicated in dark tone) to show when shading is needed on both of these dates, and other areas (in light tone) to show when shading is needed on only one of them, which is usually the autumn date. This diagram provides the basis for the evaluation of shading devices.

Determine type and position of a shading device for the overheated period. Masks can be drawn for any shading device--even for very complex ones, by geometrical methods. A protractor serves to plot the projection of a device onto the sky-vault much as the shading mask of the surroundings are charted.

Since the masks are a conventionalized geometric description, they are independent of latitude, orientation, and time. Once plotted for a specific device, the shading mask can be used in any situation. Shading devices can be grouped according to their masks into three main categories:

- Horizontal overhangs--their typical mask characteristics are segmental areas

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- Vertical louvers--their typical shading masks are bounded by radial lines
- Eggcrate types--basically combinations of horizontal and vertical devices; their mask characteristics are, accordingly, a combination.

Shading mask characteristics are independent of the device's scale; the ratio of the depth of the device to the proper dimension of the wall surface is the determining factor. This is expressed by the angle, which shows this ratio in a plane normal to the wall. The shading effect, and therefore the mask, depend on this angle. A very small-scaled device, like the "cool-shade" or an outside venetian blind, will have the same shading mask as a balconied apartment house if their angles are the same. (180) 81

Environmental controls

For energy conservation, skillful use of plants can significantly increase a building's energy efficiency. Air-conditioning requirements for most buildings result from solar energy absorption by building surfaces. By simply shading parts of the building receiving the most sun, cooling requirements can be significantly reduced. A desirable effect of planting is to cause apparent reduction in the scale of structures. The oppressive feeling of monumental scale is relieved by proper planting. During summer, trees can provide shade and thus reduce cooling requirements; during winter, the bare branches of deciduous trees allow sunlight to reach exterior surfaces and thus help heat the building. (170) 53

The effects of vegetation on a site's microclimate can be considerable; trees can reduce both sunlight and windspeeds by 90 percent and temperatures by 15°F. In addition, vegetation can usually be manipulated more easily than topography or adjacent buildings. (170) 34

Deciduous trees are nature's answer to passive shading control because they shed their leaves in the winter when solar insolation is most welcome. Branches will still block some of the sun. (170) 34

e. Humidity and temperature impact

The simplest measure of humidity is the wet-bulb temperature, available from local climatological data (LCD). The more closely wet-bulb temperature matches dry-bulb temperature, the more humid the air. Wet-bulb temperatures are often mapped on a curve in tandem with dry-bulb temperatures for an estimate of humidity. (170) 18

For designing, perhaps the easiest measurement of humidity is "relative humidity"--the percentage of water in the air compared to the maximum it can hold at a given temperature. At 100 percent

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relative humidity, the air cannot hold any more moisture; precipitation will occur should the temperature drop. Relative humidity data, available from LCDs, can be grouped in the same format as wet-bulb temperatures. (170) 18

The comfort range of relative humidity depends on the dry-bulb temperature, and can be from 20 to 60 percent. (170) 18

Excess humidity is a problem only during the cooling season. Most energy-conserving design options do not deal with humidity directly but rather increase natural ventilation and disiccant cooling to make a humid environment more comfortable; conversely, pools and fountains added to a dry site can make it feel cooler. (170) 18

Dry-bulb temperature is the most basic indicator of the site's comfort needs. The most basic climatic analysis relies on: (170) 9

- Temperature means and extremes
- Design temperatures
- Diurnal temperature swings
- Degree days or degree hours.

NOAA's LCD summaries provide annual and monthly means, that is, average or normal, and extreme temperatures over a 30-year period. Daily maximum and minimum temperatures provide the mean low and high temperatures for each month. The monthly mean temperatures give the average temperature for the entire month. The climatic atlas also provides these data. (170) 9

Designing the record high and low temperatures, especially when using natural conservation strategies, is not usually an optimal economic solution. It is better to design for the high summer and low winter temperatures that occur 95 or 97.5 percent of the time. The Fundamentals handbook prepared by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) lists high summer temperatures as 1 percent, 2.5 percent, and 5 percent and low winter temperatures for 95 percent and 97.5 percent for almost 800 locations across the United States. (170) 9

Many passive energy-conserving strategies, such as thermal mass storage and night ventilation, depend on the temperature that occurs on a 24-hour cycle. Diurnal temperature swings can be as great as 40°F in some areas of the country, allowing summer heat accumulated in the daytime to be released during the cool night. (170) 9

Diurnal temperature swings can be plotted from LCDs for each month. The summary sheet for each month contains a "summary by

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hours" chart on the first page, presenting average monthly temperatures at 3-hour intervals. These data can be graphed on a chart similar to the IVA format. A diurnal swing of 20°F or higher indicates that thermal mass storage or night ventilation could be an effective strategy.

"Degree days" are based on a selected indoor design temperature, usually 65°F, and measure the amount of heating or cooling needed in an area. Heating degree days are determined by multiplying the number of degrees difference between the average outdoor temperature and the specified indoor temperature times the number of days the outdoor temperature occurs. Adding hourly totals gives degree days per month. ([172] 11). Cooling degree days are calculated by the same procedure. (170) 12

This information is used when calculating the annual heating or cooling loads of a building ([172] 11). When the temperature is above 65°F, the hourly component is computed as zero.

Topography

Landforms are a prime example of a microclimate modifier. Atmospheric temperature decreases with altitude. The temperature drop in the mountains can be approximated as 1°F for each 330-foot rise in summer and for each 400-foot rise in winter. (169a) 4.12

Since mountains affect the macroclimate, small differences in terrain can modify the microclimate remarkably. Cool air is heavier than warm, and at night the outgoing radiation causes a cold-air layer to form near the ground surface. The cold air acts like any liquid, flowing toward the lowest points. This "flood of cold air" causes "cold islands," or "cold-air puddles." Accordingly, elevations that impede air flow affect the distribution of the nocturnal temperatures by dam action, and concave terrain formations become cold-air lakes at night. The same phenomenon increases when a large volume of cold air flow is involved, as in valleys. The following example illustrates this phenomenon. (169a) 4.12

A plateau, valley walls, and bottom surface cool at night. Air flow is toward the valley floor. On the valley slopes, a series of smaller circulations mix with the neighboring warm air, causing intermediate temperature conditions. Accordingly, the temperatures at the plateau will be cold; the valley floor will be very cold, but the higher sides of the slopes will remain warm. This area is called the "warm slope" (thermal belt). In temperature zones, the thermal belt is the most advantageous place for a building. However, if this location is exposed to crest winds that may offset higher temperatures, a more desirable place would be approximately halfway up the slope. (169a) 4.12

Water

Water bodies also affect the microclimate. Water has a higher

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specific heat than land and is normally warmer in winter and cooler in summer, and usually cooler during the day and warmer at night, than the terrain. Accordingly, the nearness of water bodies moderates extreme temperature variations, raising the minima in winter and lowering the heat peaks in summer. In the Great Lakes region, this effect raises the average January temperatures about 5°F, the absolute minimum temperature about 10°F, and the annual minimum about 15°F. Average July temperature is decreased about 5°F. In diurnal temperature variations, when land is warmer than water, low, cool air moves over the land to replace the updraft. During the day, such offshore breezes may have a cooling effect of 10°F. At night the direction is reversed. The effects depend on the size of the water body and are more pronounced along the lee side. (169a) 4.13

Vegetation

Vegetation must also be considered part of the microclimate. The natural cover of the terrain tends to moderate extreme temperatures and stabilize conditions through the reflective qualities of various surfaces. Plant and grassy covers reduce temperatures by absorbing insolation and cool by evaporation. This reduction can amount to 1500 British thermal units per square foot per season. It is generally found that temperatures over grassy surfaces are about 10 to 14°F cooler than those of exposed soil on sunny summer days. (169a) 4.13

The effectiveness of specific plant materials in climate control depends on: (169a) 4.13

- The form and character of the plant
- The climate of the region
- The specific requirements of the site.

Vegetation can absorb over 90 percent of light falling on it, reduce wind speeds by 90 percent, or increase them. It can also reduce daytime temperatures by as much 15°F and, in certain situations, raise nighttime temperatures. (169a) 4.13

Basically, vegetation controls the sun's effect by filtering direct solar radiation, which limits the amount of heat reaching the ground surface. (169a) 4.13

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SB2
Communication Facility Buildings

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COMMUNICATION STATION BUILDINGS

function

DCS facilities should use economical, completely functional architectural and engineering design to facilitate DCS missions and their future modifications. Provide dependable, high-quality, electric power to assure continuity of communications. (19) Vol 1, 6; and provide environmental conditions with 99.99 percent operational ability under stress. (19) Vol 2, 5

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Structural/Architectural

1. Functional design

All military facility planning shall use economical, completely functional architectural and engineering design, closely tailored to the carefully determined actual requirements of the project, with particular attention to the selection of interior and exterior finishes, and to the type and extent of the services and equipment provided. Special studies will be made for specific projects when necessary to determine the most economical, practical type of structure, methods and systems of construction, materials, finishes, services, and equipment to be used. Design will be closely governed by functional requirements, will conform to existing DOD standards and criteria, and will be consistent with applicable Congressional cost limitations. Facilities will be provided at the lowest practical cost per square foot that can be attained while achieving optimal life cycle cost design. (136) 5-1.

2. Design excellence

Achievements of excellence in architectural design shall be a prime goal for all military construction projects. Reaching this goal requires a commitment by designers and administrators to architectural quality, which includes the physical linkages of architecture to the surrounding community, and the design details that affect a building's users. Proper attention shall be paid to construction economy, including life cycle cost, functional requirements of the project, energy use, interior and exterior detail, siting, and reaching aesthetic solutions compatible with neighbors and local environment. (136) 5-1

The structural systems and materials to be selected shall be (a) suitable for permanent type military facilities, (b) able to carry the required loads, and (c) compatible with fire protection requirements and architectural and functional concepts. (136) 6-1

In choosing structural materials for a specific project, consideration shall be given to (a) the site environment, including climate, subsurface conditions, accessibility, wind velocity, and seismic ratings; (b) skill and experience of prospective contractors; (c) the design life of the facility and maintenance costs over this

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period; (d) experience of design and inspection personnel; (e) availability of labor and materials; and (f) the feasibility of preassembling or precasting major structural elements.

Mechanical

1. For DCS facilities, the term "air-conditioning" is synonymous with "environmental control," which is the process of simultaneously controlling the temperature, relative humidity, air cleanliness, and air motion in a space to meet occupant, a process, or equipment requirements. (19) Vol 2, 4

2. Energy conservation should always be considered in designing the air-conditioning system. However, the operating environmental conditions specified by the communications equipment manufacturer should be the primary consideration governing air-conditioning system design. Numerous publications are available from various Federal agencies and military departments that provide substantial information on alternative energy sources and energy conservation methods, techniques, and equipment. The system designer should consider all applicable design parameters to provide the most reliable, energy efficient air-conditioning. When feasible and cost-effective, energy conservation measures should be incorporated in the air-conditioning system design. (19) Vol 2, 10.

3. The air-conditioning load should be estimated in accordance with criteria in the ASHRAE Guide and Data Book. Other commercially recognized load estimating methods using the criteria from the ASHRAE Guide and Data Book are acceptable. Computer energy programs are acceptable and their use is encouraged, as they provide heating and cooling load profiles for a typical year using a typical year's weather data. Heating and cooling loads are usually calculated hourly, daily, weekly, and monthly with summaries providing peak and annual loads and respective energy consumption. Many programs can compare several different types of air-conditioning systems and select the one most energy efficient and cost-effective to meet the load estimate. (19) Vol 2, 10.

4. The selection and design of an air-conditioning system depends on many variables. Each system should be designed to provide the specific conditions peculiar to each design requirement. The designer should consider:

- Operating environmental conditions required by the communications equipment.
- Siting and outdoor environment. (See S89)
- Capacity requirements for critical areas, technical areas, and all areas combined.
- Availability of a central cooling source, a central heating source, and alternate energy sources.

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- e. Availability and quality of water.
 - f. Availability and quality of commercial utilities.
 - g. Availability of spare parts and maintenance items.
 - h. Availability of skilled maintenance personnel.
 - i. System installation costs and annual O&M costs, including annual energy consumption and cost. (19) Vol 2, 10
5. The air-conditioning system should be designed so that it will not interfere with the communications systems it serves. Operation of system components should not cause voltage fluctuations in the electrical power systems serving the communications equipment. Electric wiring to the air-conditioning system should not cause electromagnetic interference to the communications system. Attention should be given to both radiated and conducted forms of interference, plant layout, and cable shielding and routing. Electromagnetic interference characteristics for air-conditioning equipment and wiring should meet the applicable Class A3 requirements in MIL-STD-461B.
6. The air-conditioning system should be designed to provide the environmental conditions necessary for the DCS installation to maintain 99.99 percent operation. To meet this requirement, a secondary or auxiliary air-conditioning system, subsystem, equipment or components should be provided for areas containing communications equipment and systems that would not be operational if the primary air-conditioning system failed. These units should be able to provide the environmental conditions necessary for the critical areas to remain operational. Generally, these areas contain data processing equipment and may include AUTODIN switches. The air-conditioning designer should determine what is required for the secondary or auxiliary air-conditioning system. Also, spare parts and service supplies recommended by the equipment manufacturers should be readily accessible for maintenance and repair work for both the primary and secondary air-conditioning systems. (19) Vol 2, 11. When designing the secondary system, each piece of electronic equipment should be carefully investigated for its true ventilation, temperature, and humidity control requirements. (40) 7-3
7. Air-conditioning equipment should be located in areas that delay or defer intruders. Utilities and storage tanks should be installed underground. Air-conditioning equipment such as air-handling units, boilers, pumps, compressors, and associated equipment should be installed in a mechanical equipment room inside the structure it is supporting. Equipment installed outside the structure, for example, condensers and cooling towers, should be installed at grade level and provided with fences, walls, barriers, or revetments. (19) Vol 2, 16
8. The air-conditioning installation contractor should be required to provide as-built drawings and copies of operating, maintenance, and repair manuals for the system and each of its components. For overseas installation, drawings and manuals should also be in the language of the foreign nationals who will maintain the system. The operating

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instructions, the preventive maintenance schedule, the wiring and control diagrams and the detailed control sequence should be framed under glass or plastic and should be posted in a suitable location in the mechanical equipment room. Additionally, the contractor should be required to furnish a list of recommended spare parts and service supplies.

Electrical

1. The complete electrical distribution system shall be designed in accordance with the National Electric Code. (5) 3-4-8

The total power distribution system shall be divided into two separate parts: (a) technical power with a panel for the C-E equipment and (b) utility power with a panel for HVAC, lighting, and other systems. By using two systems, filter requirements can be reduced to those for technical power only.

2. The quality of electrical power for digital, synchronous, and automated switching equipment shall be free from power abnormalities that may cause loss of synchronization, discontinuity of the switching function, or physical damage to the electronic equipment. (19) Vol 1, 6

3. Power systems shall be designed to provide the specific power characteristics required by each DCS facility. This involves judicious selection of the primary and auxiliary power sources, uninterruptible power systems (UPS) or other power conditioning equipment, secondary substations, and the distribution system to attain the maximum overall system performance with the most cost-effective design. Initiative and engineering judgment must be exercised considering the assigned mission in each individual case. (19) Vol 1, 6

4. The power system shall be of uncomplicated design consistent with established requirements and assigned mission. Complex circuitry and switching schemes shall be avoided. Distribution circuits and system components shall be protected by positive acting protective devices capable of coordination throughout the primary distribution and secondary power and lighting systems. (19) Vol 1, 6

5. For all designs and upgrade of DCS power systems that require power generating sources, such as diesel generators, consider and, if possible, use the DOD Standard Family of Mobile Electric Power Generating Sources defined in the current series of MIL-STD-633. All power and lighting systems supporting the DCS shall be designed to meet the requirements of the National Electric Code. (19) Vol 1, 6

6. Major components of power facilities should be designated as recoverable whenever possible, so that cost savings and operational flexibility can be attained when facility relocation is required.

7. The primary power source and distribution system shall be engineered and designed to provide optimal reliability at the lowest overall cost, considering initial installation and O&M. Reliable power systems usually require auxiliary power supplies, including emergency generators

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and UPS. The amount and class of auxiliary power required at facilities is determined by the degree of reliability dictated by strategic and operational considerations. (19) Vol 1, 7

8. The system shall be able to provide and distribute the present load and be readily reconfigured to accommodate future mission activity and improvements. Operational flexibility requires alternative sources, feeders, buses, switching arrangement, and test arrangements. (19) Vol 1, 7

9. Power and internal distribution systems shall be designed to enable any facility to remain in service during deenergization of selected system components for maintenance, testing, and replacement. Failure of any one major component of the power system (transformers, prime power source, auxiliary power source, secondary switchgear) should not cause the facility to become nonoperational. Strategically placed test points should be included to enhance troubleshooting and problem isolation. (19) Vol 1, 7

10. Auxiliary equipment should be electrically isolated to prevent electronic system interference. (19) Vol 1, 7

11. The primary power supply, auxiliary power supply, and distribution system shall be engineered to provide 99.99 percent availability to the technical load bus(es). (1) 12

12. On-station prime power plants are considered only when local power is either extremely unreliable or prohibitively expensive, when no power is available, or when self-sufficiency is required for survival and reliability in a wartime environment. (1) 31 See also Issues and Assumptions (para 4).

ISSUES AND ASSUMPTIONS**Mechanical****1. "Critical" versus "technical" equipment areas**

Critical areas are first priority and therefore, for environmental system design, critical spaces or rooms are operational spaces that contain communications equipment and require specific temperature and humidity for operation. Technical spaces are considered rooms or areas that contain communications equipment or other equipment that supports communication systems, yet requires specific temperature limits. (19) Vol 2, 4

2. Defining acceptable rate of temperature change for critical areas

Some manufacturers of electronic data processing equipment specify close limitations on the allowable rate of temperature change. For existing AUTODIN switching facilities and some other DCS facilities, the computer equipment manufacturer has specified that the maximum allowable

issues and assumptions

rate of temperature change is 1.7°C (3°F) per hour. No stipulation is made for the location or the time period for making the temperature change measurement. This requirement can be interpreted as meaning that temperature fluctuation (up and down) of more than 0.14°C (0.25°F) in 5 minutes, or 0.03°C (0.05°F) in 1 minute, or 0.0046°C (0.008°F) in 10 seconds cannot be tolerated because computer operation would be adversely affected. Such small increments cannot be measured or recorded with available standard temperature recorders. Additionally, such small temperature changes can occur in any room during normal operation of the air-conditioning system. Therefore, for all future installations, when a computer manufacturer specifies a maximum allowable rate of temperature change, it should be expressed for no less than the smallest time period during which the specified change can be measured and recorded by automatic temperature recorders currently available on the market. The time specified should be the smallest time duration of changing temperature that will adversely affect the computer. Also, the manufacturer must specify the exact location where the measurements are to be made. (19) Vol 2, 7

Electrical**1. Nonstandard power frequencies and voltages in host countries**

Many voltage and phase arrangements are in use in current DCS facilities to fulfill currently installed electronic equipment demands. Facilities required to use host country power that has nonstandard frequency and voltage must be specifically engineered to meet electronic equipment requirements (19) Vol 1, 6

2. Government-owned power system versus host country delivered power

Primary power can be furnished by an off-station source (a commercial company or a Government-owned power system) or generated locally at the facility. The power source should be determined from an economical and technical analysis of all available power sources with consideration given to combinations of renewable energy sources. (19) Vol 1, 10

The utility company will usually deliver off-station power to the facility. An investigation shall be made of the supplier's ability to serve the present load and the load projected over the next 5 years. A study shall be made to evaluate system outages over the last 5 years. The voltage and frequency stability and other system characteristics should be determined. In addition, commercial plants connected to the primary feeder must be studied for transient or erratic regulation conditions they may cause to the distribution system. (19) Vol 1, 10

In planning and engineering Government-owned power systems, the following must be considered: simplicity, reliability, flexibility, operability, maintainability, quality, cost-effectiveness, synchronization location, sources, power conditioning, UPS, float battery, electromagnetic compatibility, survivability, recoverability, and environment. (19) Vol 1, 6

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3. Automatic versus manual auxiliary power transfer

The synchronizing auxiliary power plants' ability to permit technical load assumption by an auxiliary power plant or to return from auxiliary power to primary power after a power failure without power interruption is a requirement for DCS facilities. As a minimum, the synchronizing and transfer system should be activated manually while the preferred method would operate automatically after a predetermined, adjustable time after the return of primary power. (19) Vol 1, 7

4. Commercial power versus independent plant

Two primary power sources will be considered: a large-scale commercial (or possibly private or military) power plant and an independent on-site generating plant. A "commercial" power source usually means the nearest power transmission line. For larger terminal stations in the United States, the choice of commercial power is almost taken for granted because power lines are likely to be available at such sites. For stations at remote sites, the choice of an independent power plant may also be taken for granted since power lines are not likely to be nearby. But for the majority of stations, a comparison must be made between the installation, occasional maintenance, and service line costs for existing power lines and the installation, regular maintenance, and depreciation costs of an independent power plant before a decision can be made. (70) 14-1

5. Number of generators as an on-station power source

On-station prime power plants normally use multiple sets of DOD standard family diesel engine generator sets for the power source. Other sources (such as gas turbine generators, steam turbine generators, and nonstandard diesel engine generators) can also be used and should be considered when requirements dictate. An on-station prime power plant will use a minimum of three generator sets with one set online and carrying the station load, one set as a standby, and one set as a maintenance spare. A more reliable configuration is to use four or five generator sets with two sets online in a load-sharing mode, one as a cold standby unit, and one or two as maintenance spares. (87) II-83

6. Determining the need for uninterruptable power supply (UPS)

In some cases, a UPS may be necessary to supply a critical technical load. The method used depends on power requirements, line voltage, and frequency deviations that the critical technical load can tolerate. In general, a UPS system is not practical for a large transmitting facility; however, there may be cases when it is necessary to ensure continuity for some critical receiving circuits. In these cases, a small- or medium-size UPS might be in order. (87) Vol 2, 87

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DOD Standard Family Generator Characteristics (87) II-84

kW	Freq (Hz)	Type Engine	No. 0	MTBF (hours)	Classification Type/Class	fp	Model No.
60	50/60	Diesel	3	500	1/2	0.8	006A
60	50/60	Diesel	3	500	1/1	0.8	105A
60	400	Diesel	3	500	1/1	0.8	115A
60	400	Gas Turbine	3	1500	1/2	0.8	404A
83.3/100	50/60	Diesel	3	500	1/2	0.8	007B
83.3/100	50/60	Diesel	3	500	1/1	0.8	106B
100	400	Diesel	3	500	1/1	0.8	116B
167/200	50/60	Diesel	3	500	1/2	0.8	009A
167/200	50/60	Diesel	3	500	1/2	0.8	009A
417/500	50/60	Diesel	3	500	1/2	0.8	011A
417/500	50/60	Diesel	3	500	1/2	0.8	029A
625/750	50/60	Diesel	3	1500	1/2	0.8	409A
625/750	50/60	Diesel	3	1200	1/2	0.8	208A

requirements	criteria	commentary
ARCHITECTURAL		
1. Exterior closure	1. a. Exterior walls designed to protect the DCS and facilitate module construction for DCS building expansion. b. Exterior doors and windows for operations, power, administrative and personnel support spaces. (See SB7-"Security Systems" for information about limitations on exterior windows) c. Thermal protection in exterior closure.	
2. Interior construction	2. Interior building materials relevant to DCS activities--adjustability, efficiency, choice, and comfort. a. Interior partitions designed to facilitate modular space layouts. 1. Full-height partitions. 2. Partial partitions to define workstations. b. Floor and ceiling systems for DCS equipment loading and cable connections. (See "Electrical" section for information on lighting fixtures and cable trays,etc.) 1. Concrete slabs with access ducts for power and signal cables. 2. Floor and ceiling construction. 3. Building components for mechanical, electrical, and communication accessibility. c. Interior doors and windows for operations, power, administrative, and personnel support spaces.	2.a. See reference 201, page 3-4, Table 3-2.
3. Interior finishes	3. Interior finishes relevant to DCS activities and personnel efficiency. 1. Flooring 2. Walls.	

requirements	criteria	commentary
4. Special components	4. a. Radiofrequency interference (RFI) shielding. (See SB4--"Grounding/Bonding/Shielding" for additional guidance) b. EMP/EMP protection. (See SB5--"EMP/HEMP Protection" for additional guidance.) c. Building penetration resistance--"Hardening." (See SB7--"Security Systems" for additional guidance.) d. Vault construction. (See SB7--"Security Systems" for additional guidance.) e. Special protective design. (See SB8--"Survivability" for additional guidance.)	
MECHANICAL		
1. Plumbing	1. Plumbing systems relevant for DCS building operations.	
2. Heating, ventilating, and air-conditioning	2. a. Select the outdoor design conditions necessary to generate the optimal HVAC system. 1. Summer outdoor design conditions. 2. Winter outdoor design conditions. 3. Air-cooled condensers. 4. Cooling towers and evaporative conditions. 5. Water coolers and glycol coolers.	2.a. The Departments of the Army, Navy, and Air Force triservice manual, Engineering Weather Data (AFM 88-29; TM 5-785; NAVFAC P-89), should be used to select summer and winter outdoor design conditions. For locations not covered in this manual, the respective MILDEP should provide the summer and winter outdoor design conditions. See also SB9--"Climate conditions" for further guidance. Outdoor design conditions should be selected on the basis described below. (19) Vol 2,5.

requirements	criteria	commentary
3. Special mechanical	b. Select the indoor design conditions necessary to generate the optimal HVAC control. 1. Critical areas--temperature tolerance and humidity control. 2. Technical areas--temperature control. 3. Outdoor air ventilation rates and room pressurization. 4. Air cleanliness. 5. CBR protection. (See SBB--"Survivability" for additional guidance.) 6. Room air velocity. 7. Sound level.	b. The selection of indoor design conditions depends primarily on the environment specified by the manufacturer of the communications equipment. Communications equipment is sensitive to ambient dry bulb temperature, relative humidity, and dust. In some instances, certain components of the communications equipment or data processing systems may have conditioned air or chilled water supplied directly to them, in addition to conditioned room air as described in this section. (19) Vol 2, 6
	3. Select suitable, unique HVAC components to generate the complete system capable of 99.99 percent operational efficiency. a. Heating systems. b. Refrigeration systems. c. Air-handling units. d. Humidification systems. e. Economizer air cycle. f. Controls and instrumentation. g. Energy conservation. h. UPS system(s). i. Battery room system(s).	3. There is no standard type of air-conditioning system best for a communications facility. The design engineer must analyze all the conditions, criteria, and variables inherent for each design requirement and select the system type that most fully meets all the requirements. (19) Vol 2, 12

requirements	criteria	commentary
ELECTRICAL		
1. Electrical systems	1. a. Provide dependable, high-quality, electrical power load to assure continuity of DCS communications. b. The DCS "electrical system" must be able to "distribute" the electrical load and must be readily reconfigured to accommodate future mission activity and improvements.	
2. Special electrical systems	2. Provide power and voltage requirements for C-E equipment, support equipment, and HVAC equipment. Consider providing a flexible system that will meet the facility's future potential and requirements within the DCS. a. Equipment protection. b. Communication signal protection. c. Power and voltage. d. Emergency status. e. Division of circuit loads. f. Plugs and receptacles. g. UPS and batteries. h. Cable trays.	
3. Lighting	3. Provide suitable lighting fixtures and illumination levels for DCS equipment and operation spaces. a. General lighting. b. RFI free fluorescent lighting. c. Exit lighting. d. Emergency lighting. e. Alternative lighting design. f. Visual comfort. g. Lighting design. h. Lighting system control. i. Illumination requirements for visual display terminal.	

guidance STRUCTURAL/1 Substructure**1. a. DCS activity and equipment loads for buildings and towers.****1. Static loads****a. Dead loads**

1. Structural systems.
2. Roofing/flooring. (See "Architectural/2b" this section.)
3. Overburden/fill.
4. Ceilings.
5. Mechanical equipment.
6. Electrical equipment.
7. Partitions.

b. Live loads

1. Ice/snow. (See SB9-"Climate Conditions")
2. Wind loads on antenna towers.

2. Dynamic loads

- a. Emergency power generators vibration. Power generators should be anchored properly to isolated floor pads.

b. Seismic conditions

In the case of highrise structures, wind and seismic forces constitute major problems to structural designers. Here, innovative responses can be found in refined structural systems, specific added features of the basic structure type, combination of systems, mass reduction, structural damping devices, aerodynamic shape, choice of materials, and methods of construction. The term "innovation" is used liberally and includes solutions in stages of limited use, prototype buildings, concepts in the process of testing, and informed proposals.

guidance STRUCTURAL/1 Substructure**b. Site conditions****1. Soil bearing capacity and appropriate foundation types**

Considerations in planning the foundation system include the soil type and uniformity; the soil and water distribution in the deposit; the strength and compressibility of the various strata; the type and magnitude of the forces to be resisted; the building scale, column spacing, and depth of excavation; and the availability of particular construction materials, equipment, and proprietary systems.

a. Spread footings

Used when the stratum of soil suitable for sustaining a structure is relatively shallow. Spread footings distribute the building loads over an area of soil large enough to secure adequate bearing capacity. (146) 472 The choice of a specific system to be implemented depends on building design and structural layout; spread footings can be classified according to the way in which they receive the loads. (147) 50-53

Wall footings--Generally found in nonresidential situations. Minimum footing depth is usually equal to twice the projection. If loading is relatively light, there must still be enough longitudinal reinforcement imbedded to minimize shrinkage and objectionable temperature cracks.

Column footings--The most common type of isolated or independent footing. Depth should remain constant through cross section as well as doubly reinforced (two-way). If placing the footings below the "permanent" groundwater level is unavoidable, a steel grillage footing may be used. In steel grillage footings, the beams are held by spacers placed between them, a layer of concrete 6 or 8 inches thick is placed under the lower beams, and the entire footing is encased in concrete with a minimum edge of 4 inches.

Combined footings--Generally used when walls and columns are located such that a symmetrical load distribution may not be obtained and the footing would tend to settle unevenly, such as along a property line or adjacent to an existing building. This problem will be solved by combining the wall column footing and the nearest interior footing into a single proportional footing such that the centroid of the area that bears on

guidance STRUCTURAL/1 Substructure

the soil is on the line of action of the resultant column loads. The footing shall be trapezoidal, thus producing uniform pressure distribution under the footing. However, if a rectangular footing can be proportioned so that the centroid will be on the column load line of action, the footing may be rectangular in plan.

Continuous footings--If differential settlement between columns may occur, this can help reduce the condition by tying three or more columns together with reinforced concrete slabs extended continuously under the columns. The foundation wall should be constructed as if it were a reinforced concrete girder. The footing and the wall may be poured at once or separately (which is usually done). If done as a monolith, the reinforcing steel shall be placed near the bottom of the footing, whereas if poured separately, the lower steel should be located at the bottom of the wall. Transverse reinforcing must be near the bottom of the slab as well as in the footing. Continuous footings may also support bearing as well as columns--usually desired because it reduces the differential settlement caused by variations in the soil and reduces cracking in the walls bearing on the foundation wall as well as in the foundation wall itself. C.I.P. concrete foundation walls reinforced in this way are suitable, even for small structures. The additional cost is small and the results are worth many times the cost. Two-way continuous footings are even more effective than one-way footings in reducing differential settlement as well as in providing an effective method to resist dynamic loads such as those from earthquakes.

Raft or mat foundations--Used when the soil's bearing capacity is so low that other footing systems cannot be used effectively. They are used as a single concrete slab to cover the supporting stratum under the entire area of the superstructure. If possible, the entire foundation should be poured in one operation to avoid construction joints through the lateral directions.

b. Deep footings

Deep footings such as piles and piers are to be used if the upper strata are too weak and the loads must be transferred to more suitable material and greater depths. (146) 47

Piles--Can be divided into three categories: (146) 525

1. Friction piles in coarse-grained, very permeable soil (sometimes called "compaction piles").
2. Friction piles in very fine-grained soils of low permeability (commonly known as "floating pile foundation").

guidance STRUCTURAL/1 Substructure

3. Point-bearing piles.

Types of piles

Timber--Drive to required resistance or penetration. This type of pile is low in cost but has low load bearing capacity compared to others, and must be treated to resist attack by marine borers and termites.

Concrete (cast-in-place)

1. Uncased drilled pile--A hole is to be bored into the ground with a drilling machine and concrete is then cast into the open hole. Caution must be taken to insure that the soil is cohesive so that caving of the shaft walls will not occur. Location of groundwater may also cause difficulties and one must be aware that the concrete can become easily mixed with dirt during casting.
2. Raymond piles--Tapered steel shell to be driven to required resistance or penetration by an internal steel mandrel. Withdraw mandrel leaving steel shell in ground and fill shell with concrete. This method prevents dirt from mixing with concrete. The shell must be strong enough to resist collapse under pressure from the surrounding soil.

Concrete (precast)

Driven to required resistance or penetration with a comparatively soft cushion block to protect the head of the pile. These piles are useful when it may not be feasible to use cast-in-place piles. Good for bending and uplift when reinforcement is used. Precast concrete piles require storage space, transportation, and equipment for handling.

Steel

1. Open-end pipe pile--Drive a section of steel pipe into the ground with a drive sleeve fitted to the upper end, add a second section and continue driving, sections are then added and driven to the required resistance or penetration. Remove soil from the inside of pipe by water jets, compressed air, or augering.
2. H-pile--Simply driven to required resistance or penetration. If it is driven through cinders, ash fill, or normally active rust-producing material, adequate protection must be provided.

guidance STRUCTURAL/1 Substructure

Piers--Can be considered point bearing piles that transfer loads onto or into a firm stratum located beneath softer ones. Since piles and piers serve the same purposes, no sharp distinction can be made between the two. Cast-in-place piles installed in drill holes might preferably be considered piers of small diameter because they are constructed by procedures identical to some of the methods used for constructing larger piers. (146) 557

For drilled piers a shaft will be excavated by truck or crawler mounted drilling machine to the required depth. If a belled bottom is desired, an underreamer attachment is lowered into the shaft and a bell is cut into the soil at the bottom. When excavation is complete, concrete is filled in. A single pier often may replace a cluster of piles.

C. Basement Walls

Basement walls (concrete foundations)--These support the vertical load and withstand the lateral pressures of the soil. Usually the earth's pressure is not considered in this type of construction because its effects are small compared to the vertical loads; but, for low buildings with deep basements, the lateral pressure does become a factor. If this is the case, the walls should be properly thickened and reinforced to withstand these loads. (147) 117 Air entrainment admixtures of 2 to 3 percent are recommended but not essential. (130) 203-22

2. Soil types and groundwater implications

Soil types in a given area are often obtainable from geological maps, soils maps, and reports of subsurface investigations made on adjacent sites. These are not to replace actual subsurface exploration, but rather are a means for efficient planning of subsurface investigation and laboratory testing.

Engineering characteristics of some soil types

Loose sand--A sand deposit with low density. Vibratory loads tend to densify these deposits; therefore, special measures must be taken in designing foundations for buildings that will house machines, because the vibrations from their operation may induce intolerable settlements. Loose sands also present problems in high seismic risk areas, because seismic loading can induce liquefaction, if the sand is saturated, as well as cause significant settlement. (145) 8

guidance STRUCTURAL/2 Superstructure Systems

Loess--A deposit of relatively uniform, windblown silt. Loess soils become very compressible when saturated. This often causes problems with hydraulic structures such as canals and earth dams that are constructed on loess foundations. Special design measures are necessary for these cases; for example, prewetting the foundation may be necessary to induce settlement before starting construction. (145) 9

Normally consolidated clays--Clay soils that have never been subjected to a pressure greater than the existing pressure. These soils tend to be highly compressible, have a low ultimate bearing capacity, and, as with all clay soils, have very low permeability. Because of the low ultimate bearing capacity and high compressibility, the soil is very often not able to support structures on shallow foundations. In these cases, other foundation types must be considered. One such type is pile foundations, which transfer the structural loads to a lower soil or rock strata with a higher bearing capacity. Or, a floating foundation could be used with which the quantity of soil excavated for basement levels will equal the weight of the structure. (145) 9

Overconsolidated clays--Clays that in the past were subjected to a pressure greater than the existing pressure. Highly overconsolidated clays generally tend to have rather high ultimate bearing capacity and are relatively incompressible. (145) 9

Bentonite--A highly plastic clay resulting from volcanic ash decomposition. It is an expansive soil that swells considerably when saturated. This can reduce the performance of foundations, sidewalks, concrete slabs, and other structural elements if the soil is subjected to seasonal changes in water content. On the other hand, bentonite is often used beneficially as an impermeable pond liner. (145) 9

Peat--Fibrous, partly decomposed organic matter or a soil containing large amounts of fibrous organic matter. Peats have a very high void ratio and are extremely compressible; thus, they should be avoided. (145) 9

Moisture--The amount and distribution of moisture in soil have a very great effect on the soil's physical properties. The ability of a soil to support foundation loads may vary over a range of several hundred percent, depending on the percentage of moisture and type of soil. Stability of artificial and natural slopes is greatly affected by water pressure. Because of these and many other reasons, it is necessary to have accurate, complete knowledge of the soil's water condition. (145) 45

2.a. Floor and roof framing

The choice of a specific framing system depends on each specific case. One form cannot be recommended over another

guidance STRUCTURAL/2 Superstructure Systems

without knowing factors such as local availability and labor costs. Therefore, a brief overview of systems that might be applicable to DCS buildings follows.

1. Cast-in-place reinforced concrete systems

Slab-on-grade--Two types of on-grade slab construction involve (1) a slab with grade beams and (2) a slab with thickened edges, called a thickened slab. Slabs should be reinforced over the entire area and provide proper moisture protection and insulation should be provided if necessary. (147) 99

Concrete slabs on grade are considered more economical and preferable for ground floors in general, except where local site (soil) or climatic conditions are not suitable. (138) 3-10

One-way systems--Widely spaced beams (8 feet on-center) that generally have a normal maximum span of 40 feet, as does narrowly spaced beam systems. Both systems have the advantages of easy provision for openings and adaptability. Joists have the same advantages as the beam, plus reduced formwork costs (35-foot span). If a flat underside is desired or if thermal resistance is a factor, tube slabs may be implemented. If structural thickness is of major concern, a slab band should be used.

Two-way systems--Can be divided into two categories: boundary-supported and point-supported. Boundary-supported systems are just as the name implies--supported at the outer edge of the framing system by beams or girders. Point-supported systems are supported solely at the columns. Boundary-supported solid slabs and point-supported flat slab with capitals and drop panels are very similar in the sense that both have the flat underside as well as a reduced structural thickness. Ribbed or waffle slabs are functionally almost identical in both categories. They have visual appeal that complements the structurally reduced weight of the ribbed system. To provide minimum thickness for the framing, a flat plate can be used (for spans $\leq$ 30 feet).

All of the above systems may have an even further reduced thickness and increased maximum span if posttensioning is adopted.

Pretensioned cored slabs are efficient for spans of 35 feet or less with the added attributes of a flat underside, greater fire resistance, good control of airborne sound, and space provided for electrical and heating elements.

2. Steel systems

These systems are, in general, efficient, speedy, simple, readily available and familiar. Systems most applicable are beam, girder and column combination, steel joists, and long-span metal deck with a concrete slab topping. All may be composite or noncomposite. If long spans

guidance STRUCTURAL/2 Superstructure Systems

are functionally essential, long-span joists or trusses may be used to provide spans up to 150 feet. Adequate lateral bracing must be incorporated to resist wind, earthquake, and blast loads.

3. Precast concrete systems (including tilt-up)

Although it may not always be advantageous, nearly every concrete member that can be cast in place can be precast, such as floor and roof slabs, wall panels, bearing walls and partitions, joists, beams, girders, columns, rigid frames, arches, domes, and piles. Precast systems may be used advantageously if quality control is a factor, if a minimum amount of jobsite storage space is available, or if weather does not permit cast-in-place systems. Structural connections are critical in precast systems, especially in areas susceptible to earthquake.

4. DCS structures for hardened construction. (See SB7--"Security Systems" for information on DCS vaults.)

Above-ground buildings--See SB7--"Security Systems--Building Penetration Resistance" for additional guidance.

Underground bunkers--See SB8--"Survivability Protection" for additional guidance.

b. Analysis and evaluation of DCS buildings and antenna tower structural system stability:

1. Factors related to DCS buildings and towers stability:

a. External

1. Equilibrium and conditional equations.
2. Geometric conditions.

b. Internal

1. Beams.
2. Trusses.
3. Frames.

Permanent communication buildings shall be windowless structures of masonry, concrete or both, providing open space free of columns and similar obstructions. Buildings housing electronic equipment shall be of noncombustible construction. When practical, operating spaces should be designed for resistance to blast, earthquakes, hurricanes, and typhoons. Overseas, locally available materials and methods shall be used whenever possible. (92) 12.1-12

2. Evaluation of structural component stability--stabilizing structural systems

1. Moment resisting frames

guidance STRUCTURAL/3 Roof

2. Structural bracing
 - a. Diagonal/X types.
 - b. K types.
 - c. Portal.
 - d. Knee.
 - e. Extended joist.
3. Diaphragm
 - a. Walls
 - b. Floors
3. Evaluation of structural component stability
 1. Total system.
 2. Individual building components.
3. Roof systems for specific climate conditions at DCS sites: (See SB9--"Climatic Conditions" for additional information about snow loadings, etc.)
 1. Roof slopes
 2. Roofing materials

See SB7--"Security Systems" for conventional roofing materials in use and suggested hardening procedures. Roofs shall be constructed of noncombustible materials. When high-altitude electromagnetic pulse protection must be considered, metal roof deck is preferred; elsewhere, precast or cast-in-place concrete is preferred. All roof construction shall conform to the requirements of DOD 4270.1-M and NAVFAC DM-8. (92)
1. a. Exterior Walls designed to protect the DCS and facilitate modular construction for DCS building expansions:
 1. Above-ground wall construction for hardened facilities

See SB7--"Security Systems--Building Penetration Resistance" for information.
 2. Underground bunkers

See SB8--"Survivability" for additional guidance.
 3. Modular exterior wall construction

Precast concrete panels -

Prefabricated metal panels -
- b. Exterior doors and windows for operations, power, administrative and personnel support spaces: (See SB7--"Security Systems" for information about limitations on exterior windows and doors.)

guidance ARCHITECTURAL/1 Exterior Closure

1. Primary entrance door

This door should be secured with a jimmy-proof, dead-bolt extension, operated by a combination lock in conformance with the provisions of UL Standard 768 and Military Specification MIL-L-15596. The primary entrance door should also be equipped with panic bolts and rim, with box mullion, to conform with the provisions of Federal Specification FF-H-106. The panic bolts should be approved by Underwriters Laboratories, Inc. If required for routine access control, the installation of an electrically controlled and operated latch mechanism is authorized. RF emissions should meet the requirements of MIL-STD-461 of class II-A equipment. (5) 3-5-9
2. Emergency exits

All exterior doors, except for the primary, secondary, and maintenance/utility entrances not permitting ingress to administrative/operational spaces, should be equipped with panic bolts and rim, with (if double-leaf) box mullion. Alarm Lock Corporation Model 70R may also be used. Panic hardware on emergency exits should be installed "blind," without exterior handles, knobs, or operating cylinders. All panic hardware must bear the label of the Underwriters Laboratories, Inc. (5) 3-5-9
3. Maintenance/utility entrance doors

Maintenance/utility entrance doors not permitting ingress to administrative/operational spaces should be secured with a heavy, cylindrical case lock and latch sets, in conformance with Federal Specification FF-H-106 and with the provisions of Builders Hardware Manufacturers Association Standard 601. Externally accessible doors and hatches that provide access to critical utilities should be secured with padlocks and hasps in conformance with Military Specification MIL-P-43607 instead of or in addition to the cylindrical case or bored locksets specified above. (5) 3-5-9
4. Roof doors and hatches

Roof doors and hatches should be secured internally with padlocks and hasps in conformance with Military Specification MIL-P-43607. Roof doors may also be equipped with a cylindrical case or bored lockset as specified above. Such locksets, when installed, should be mounted with the lock cylinder to the exterior. (5) 3-5-10
5. Door closers

All exterior doors should be equipped with hydraulic door closers in conformance with Federal Specification FF-H-121. (5) 3-5-10

guidance ARCHITECTURAL/2 Interior Construction**6. Cylinders and keys**

All key-operated locks and padlocks used to secure doors or hatches should be provided with an exclusive Government keyway. Primary and secondary entrances should be keyed alike without masterkeying. All interior doors shall be keyed differently and single-mastered. No key-operated cylinder should use less than 6 pins, 9 discs or wafers, or 10 levers. Warded locks should not be used. (5) 3-5-11

7. Exterior windows

Special penetration-resistant hardware should be used.

C. Thermal protection in exterior walls and roof (see SB9--"Climate Conditions" for information about temperature ranges at various DCS sites).**1. Thermal protection**

This is site-specific. For thermal insulation of walls and ceiling, noncombustible material should be used. The designer should determine the density and thickness of the insulation based on the "R" factors incorporated into the computation of the "U" factor. The "U" or overall heat transmission factor for the exterior walls and roof should not be greater than 0.15 and 0.05, respectively.

2. "U" values

"U" values should be selected to provide optimal effectiveness for the air-conditioning system. The respective military departments should validate the "U" values to be used. (19) Vol 2, 11

3. Perimeter insulation

When heated spaces are adjacent to exterior walls in slab-on-grade construction, 2-inch-thick perimeter insulation shall be installed on the interior of foundation walls. Insulation shall be installed in accordance with the ASHRAE Guide.

2. a. Interior partitions designed to facilitate modular space layouts**1. Full height partitions**

Acoustic control--Walls should be constructed to prevent the transmission of noise to adjacent areas. Walls should be constructed from the floor to the base ceiling and sealed properly. Most all activities in DCS spaces require a background noise level limited to 40 db. (201) 3-4 See Table 3-2.

Noncombustible construction--Interior partitions for stairwells, vaults, elevator hoistways, toilets, and other

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areas requiring fixed partitions shall be masonry units or concrete. Partitions in storage areas shall be of concrete masonry. (92) 12.1-13. Permanent partitions separating electronic operating spaces from other spaces shall be fire-rated and constructed in accordance with NFPA 75. All partitions using metal framing or surfacing shall be suitably bonded and grounded if required. (92) 12.1-13. All walls and partitions should be of a noncombustible material that has a flame spread rating of 25 or less. The fire resistance rating of the walls will depend on the exposure to other areas, but should not be less than 1 hour. (74) 4-9. Also, see SB3--"Fire Protection/Life Safety" for additional guidance.

Support--Partitions must be able to support significant weights in technical rooms where equipment and storage shelving may be wall-mounted.

Expansion and reuse--Partitions should be designed to facilitate modular construction on a 5-foot grid system allowing expansion and reuse of components. Interior partitions in electronic operating spaces shall be nonload-bearing and removable. Electric power and control wiring shall not be located in these partitions. (92) 12.1-13

2. Partial partitions to define workstations**b. Floor and ceiling systems for DCS equipment loading and cable connections.****1. Concrete slabs with access ducts for power and signal cables**

Floor loadings--For ordinary subgrade conditions, 4-inch-thick slabs will be used for live loads to 150 pounds per square foot, 5-inch-thick slabs will be used for up to 250 pounds per square foot, and 6-inch slabs will be used for loads to 400 pounds per square foot.

Moisture protection--A capillary water barrier and at least 36 inches of material that will not permit capillary movement of water will be used under all slab-on-grade floors in buildings.

Allowance for electronic equipment--Selection of permanent floor construction should take into consideration the placement of cables and wiring for electronic equipment. An equipotential plane conforming to MIL-HDBK-419 shall be installed in the floor of all spaces. The preferred method of placing cables and wiring is given in the BESEP for the facility. (92) 12.1-13

2. Floor and ceiling construction.

The floor upon which the computer will be located should be able to support the equipment weights specified for the system. The floor under the equipment should be true and level. For fire prevention, areas with wooden floors should

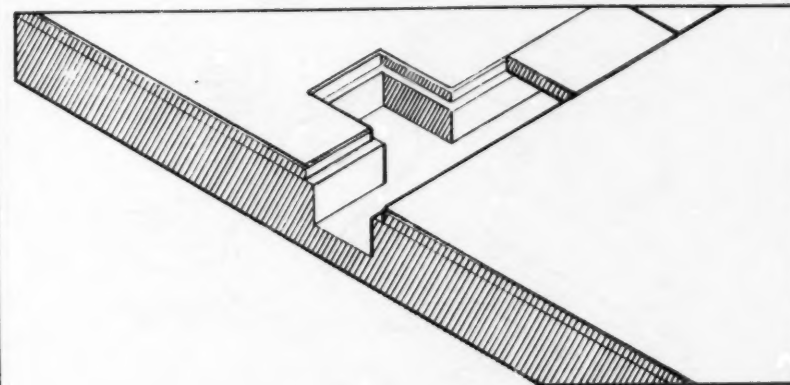
guidance ARCHITECTURAL/2 Interior Construction

not, if at all possible, be selected as sites for computer systems. (74) 4-2

Flooring is usually one of two types: raceway or false. Raceway flooring is a solid concrete floor with trenches at appropriate locations for wiring and cables (see figure). The main advantages of the raceway floor are that it is solid and virtually vibration-free. However, it offers very little flexibility. For this reason, the raceway floor is not often used in computer installations. (74) 4-7

Vibration in the computer area must be negligible. Most systems will withstand Richter scale shocks or intermittent vibrations occurring at low frequency. Commercial computers can usually stand sustained vibrations of up to 0.25 G (G = gravitational acceleration). If vibrations of greater magnitude are expected, measurements should be taken before completion of site preparations and submitted to the equipment manufacturer for approval. (74) 4-10

Computer equipment vibrations should also be considered, such as that for disks and drums. Any requirements to satisfy equipment vibration should be noted in the BESEP. The equipment manufacturer should be consulted as to measures needed to control the vibrations, if required. (74) 4-10



RACEWAY FLOOR (COVERS REMOVABLE).

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Ceiling system to provide for cable run accessibility (see SB5--"Electrical Systems" for information on lighting fixtures and cable trays, etc.)

All ducts and other systems installed in the facility as part of the finished structure should be arranged to maintain a 10-foot (3.05-meter) unobstructed clearance from the floor to the ceiling.

A commercial-type ceiling is recommended, mounted on a mechanical suspension system with removable angles or T-bars between panels. The suspended ceiling shall be of noncombustible construction, with a flame-spread rating of 25 or less (see NFPA Standard Method of Test of Surface Burning Characteristics of Building Materials, No. 255). (74) 4-9

Ceiling design shall be consistent with requirements for lighting, air-conditioning, ventilation, cable tray layout, acoustical treatment, and fire protection, as specified in the BESEP. When raised floors are used, 8 feet (2.44 meters) is the minimum clear height above the raised floor, and 10 feet (3.05 meters) is preferred. For UPS, transmitters, and similar equipment spaces for which heat dissipation is a design factor, a clear height of more than 10 feet (3.05 meters) may be required. (92)

In multistoried buildings, the floor above the computer room should be made reasonably watertight to avoid water damage to equipment. All openings, including those for beams and pipes, should be sealed to watertightness. (74) 4-9

An acoustical, suspended ceiling is recommended in the computer room to aid in reducing the noise level and to enhance the area's appearance. The suspended ceiling is practical for mounting fixtures and will conceal water pipes and air-conditioning ducts. The area above the suspended ceiling may also be used for a return air plenum, allowing greater flexibility in the location of return air grilles. Some systems require a suspended ceiling at the 96-inch height so that all cables and power wires can be routed in the overhead ceiling area. (74) 4-9

A minimum of 8-1/2 feet between the equipment floor level and the ceiling should be provided with 10 feet an optimum. In rooms with a small floor area, the ceiling should be 9 or 10 feet to insure adequate ventilation. (74) 4-9

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3. Building Components for Mechanical, Electrical, and Communication Accessibility

The DCS facility, in order to perform the crucial mission which it has been assigned, must possess the ability to quickly and efficiently receive or access information, analyze information, form solutions and make decisions, and finally, distribute or communicate those decisions to others responsible for actions. In support of their mission, many automated systems have been developed to enhance what once were tedious and time consuming tasks. Automation, while improving the productivity and efficiency within the center, has contributed significantly to the amount of mechanical, electrical, and communications cabling and supply systems which must be integrated into the DCS facility.

Unless a strategy is developed and adopted which addresses the installation, maintenance and, most importantly, the upgrade or change of the power, electronics and communications systems, the issue may become one in which the efficiency, flexibility, safety and economic feasibility of operations within the Command Center is severely jeopardized.

The Solution to the problem, once identified, is to treat it as a single issue crossing architectural, structural and electrical disciplines. The solution will lead one to a series of alternatives or combinations of alternatives available to the designer for the integration of mechanical, electrical and communications systems into the DCS facility.

The alternatives may be categorized into six generic areas with many manufacturers offering options or products within their particular area. The six areas include:

- Poke-Through
- Access Floor
- Modular Plug-in Duct
- Flexible Plug-in Wiring
- Cellular Floor
- Underfloor Duct

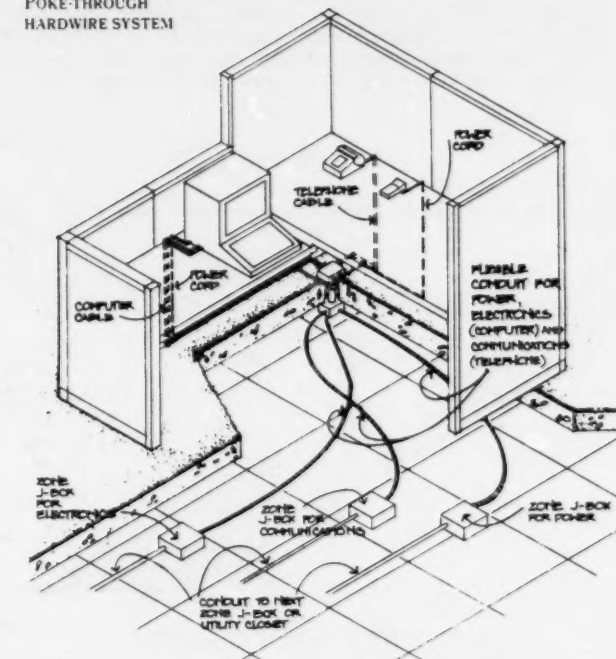
The following includes a brief discussion of each of the six categories.

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POKE-THROUGH

The Poke-through system is a delivery system consisting of a fire-rated fitting and floor outlet assembly. The outlets are installed either by core drilling the concrete floor slab or by activating preset sleeves installed within the slab. To maintain the fire rating of the concrete floor, penetrations are limited to one for every 65 sf of floor space. Poke-through usually is employed with a traditional hardware distribution system employing conduit and junction boxes.

The system provides adequate flexibility, although the outlet, which stands some 3-4 inches above the floor, must be placed where it is accessible, but not in a position where it may be a safety hazard. The major limitation with this type of system is mobility.

POKE-THROUGH
HARDWARE SYSTEM

All changes, including relocation and expansion,

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require an electrician. Rules on the number of holes permitted in the floor must also be strictly observed in order to maintain the fire rating and structural integrity of the flooring system.

Another consideration concerning the use of this type of system in a command center situation relates to the need for shielding within the room. (200) 14-26

ACCESS FLOOR

Access floor, also called raised floor, consists of panels of durable and stable construction supported on pedestals 4-12 inches above the structural floor. The panels, typically 2 feet square, can be removed to give convenient access to the floor plenum. Panels are covered with carpet squares or tile. Outlets, usually flush with the floor surface are installed in cutouts made in the panels at any location as required.

Both the distribution and delivery of power, electronic and communications services are provided through the floor plenum. Power may be enclosed in hard wire or flexible conduit, but electronics and communication can be installed without raceways when the floor is not used as an open plenum for the HVAC system.

Because the access floor does not provide for ceiling lighting, supplementary hard wire or flexible conduit is required in the ceiling plenum. Task lighting can be provided to the furniture or control consoles from the same system used for power delivery. Electronics and communication are normally delivered through the floor plenum. (200) 14-26

Advantages of access flooring systems include:

Total flexibility the placement of outlets, electronics and communication feeds

Greater flexibility in the location of furniture and equipment.

Virtually unlimited capacity to expand the power, electronic and power services. Changes can be made by simply removing the floor panels and connecting or routing new service.

The plenum space can be used for the placement of HVAC systems. This can prove very beneficial in satisfying the cooling requirements of large pieces of communications and/or data processing equipment.

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Access flooring may permit some economies in the reduction of concrete floor slab finishing.

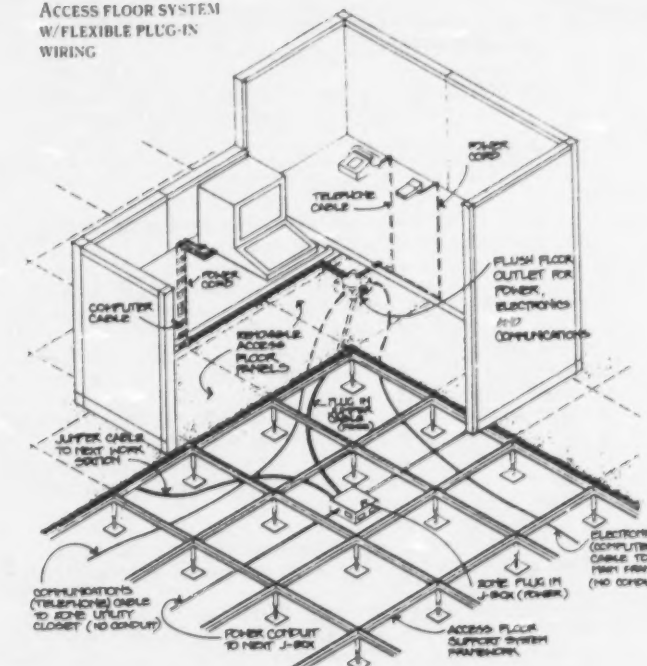
While the advantages are very attractive for the use of access flooring, there are some disadvantages, they include:

The "wobbliness" of the flooring system due to the lack of flooring mass.

The reduction in floor to ceiling height or the need to lower the area in which the access floor is to be placed.

Access floors are not watertight, therefore care must be taken so that water or spilled liquids cannot leak or drip into the plenum and on wiring.

ACCESS FLOOR SYSTEM
W/FLEXIBLE PLUG-IN
WIRING



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The use of access flooring in facilities such as the command center in which a wide variety of equipment types, sizes and weights must follow the suggested instructions and specifications in order to assure a proper installation. Suggestions for the fabrication and installation of such flooring systems are included in the following discussion.

If a new building is to be constructed, it is advantageous to install the computer room floor 18 to 24 inches lower than the normal building floor. The raised floor can then be installed flush with the normal building floor, eliminating the need for ramps.

The normal room floor (under the raised floor) should be equipped with one or more devices to warn of the presence of water in the event of a broken pipe or hose. A float-operated switch controlling both an audible alarm and a sump pump is recommended. (74) 4-9

Floor loading should be checked for both the raised floor and subfloor. In calculating loading for the subfloor, these items should be considered in addition to equipment weight: (74) 4-8

Weight of raised floor--approximately 10 pounds per square foot (48.7 kilograms per square meter).

Weight of signal cables--approximately 0.4 pound per foot (0.6 kilogram per meter).

Weight of power cables and ducts--approximately 2.0 pounds per foot (3 kilograms per meter).

Floor loads--Flooring should be able to support a uniform live load of minimum 250 pounds per square foot with maximum deflection of 0.040 inch and with permanent set not greater than 0.010 inch. Panels in place should be able to support a 1000-pound concentrated load placed on 1 square inch at any location on the panel without deflecting more than 0.080 inch and without permanent deformation in excess of 0.005 inch. The floor system should be laterally stable in all directions whether or not panels are in place.

Pedestal loads--Pedestals should be able to carry a 5000-pound axial load without permanent deformation.

Leakage--When the space below the finished floor is to be an air plenum, air leakage through the joints between panels and around the perimeter of the floor system should not exceed 0.1 cubic foot of air per minute per linear foot of joint subjected to a 0.5-inch

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water gage positive pressure in the plenum.

Bond strength of floor covering--floor covering should be bonded to panels before delivery of the panels to the site. Bonds should be strong enough to permit handling the panels with a lifting device and should be able to withstand moving caster loads up to 1000 pounds without separation of the covering from the panel.

Pedestal adhesive--Adhesive, when applied in accordance with the manufacturer's instructions, should be able to secure a pedestal in place with bonding strong enough to resist an overturning force of 1000 inch-pounds with the force applied to the top of the pedestal.

Grounding--The access floor system should be grounded for safety hazard and static suppression. Total system resistivity from the wearing surface of the floor to the ground connection as measured on the completed installation shall be between 5 x 10 ohms and 2 x 10 ohms. Exposed metal will not be allowed at that wearing surface of the floor. Ground connection should be made to the power equipment ground grid.

Components--The floor system should be stringer type. All components of the floor system other than the wearing surface and wood core panels should be of noncombustible construction. Wood core panels should have flame spread rating of 25 or less when tested in accordance with ASTM E 84.

Pedestals. Each pedestal should be capable of a 2-inch minimum vertical adjustment with a means provided for locking this adjustment. Bases should provide a nominal bearing area of 16 square inches. Leveling features should allow for overall floor adjustment to within 0.10 inch.

Stringers. Stringers should be made of extruded aluminum or zinc-coated steel, should interlock or key with the pedestal heads, and should be rigid enough to resist denting or deforming with rough handling. Interfacing between panel and stringer should provide sound-deadening, positive electrical grounding of all metal components, and complete plenum sealing.

Panels. Panels should be 24 x 24 inches except for edge panels. Finished panels should be within a 0.015 inch tolerance of panel nominal size, and should be square within a tolerance of 0.020 inch. Panels should be aluminum, steel, or metal-clad

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wood core.

Aluminum panels. These should be die-cast.

Steel panels. These should be die-form construction. Panels should be chemically cleaned, bonded, and given a baked enamel finish standard with the floor manufacturer. Wood cores should be particle board conforming to Com. Std. CS 236, type 1, grade B, class 2, or plywood conforming to Prod. Std PS 1, EXT-DFPA-C-C, not less than 1 inch thick. They should be faced on both sides with structurally bonded zinc-coated steel shells and sealed on all four edges with zinc-coated steel or extruded aluminum. Steel sheets should be no lighter than 24-gage, and should be zinc-coated.

Composite Panels: These panels are formed using steel or metal pans which are in turn filled with lightweight concrete. The composite panel is much less susceptible to the deflection and wobbly feeling apparent with most raised or access floor systems.

Floor finish. Panels should be surfaced with plastic laminate that conforms to NEMA LD 3, grade HW 120. Color should be selected from the manufacturer's standards. Adhesive for floor covering should be moisture-resistant as recommended by the floor covering manufacturer.

Edge strips. Vinyl edging should provide a wearing depth equal to the thickness of the floor covering and an exposed top face of approximately 1/8 inch. Edging should form a seal between adjacent installed panels. Edge strips should be mechanically locked or bonded in place. All cutouts should be edged with the same material. Bolt heads or similar attachments should not pierce the tile traffic surface.

Cover base. Cover base should be rubber or vinyl, top-set type, 1/8 inch thick, 4 inches high, and should have molded external and internal corners and end pieces.

Accessories. Registers, grilles, perforated panels, and plenum dividers should be provided as required and should be the manufacturer's standard type. The registers, grilles, and perforated panels should be designed to support the same loads as the floor panels. Grilles and perforated panels should be equipped with adjustable dampers.

guidance ARCHITECTURAL/2 Interior Construction

Installation--Free ends of the floor, where the floor system does not abut wall or other construction, should be positive anchorage and rigid support. Environmental conditions in areas receiving raised flooring shall be maintained at 50 percent relative humidity for 24 hours prior to and during installation.

New construction slabs--Concrete floors below raised flooring--These areas shall be treated with hardener and shall be covered with raised flooring. The area between the concrete floor and raised floor can be used as a plenum.

Retrofits--To retrofit existing buildings, an exposed concrete floor should be sealed if the enclosed area is to be used as a plenum. Unsealed concrete slabs will continue to lose cement fines as a concrete dust that will be drawn up into the C-E equipment with the supply air. A water-based, pigmented epoxy sealer enables workers to easily see where they have covered the floor in retrofits for a raised floor already installed over an existing exposed slab.

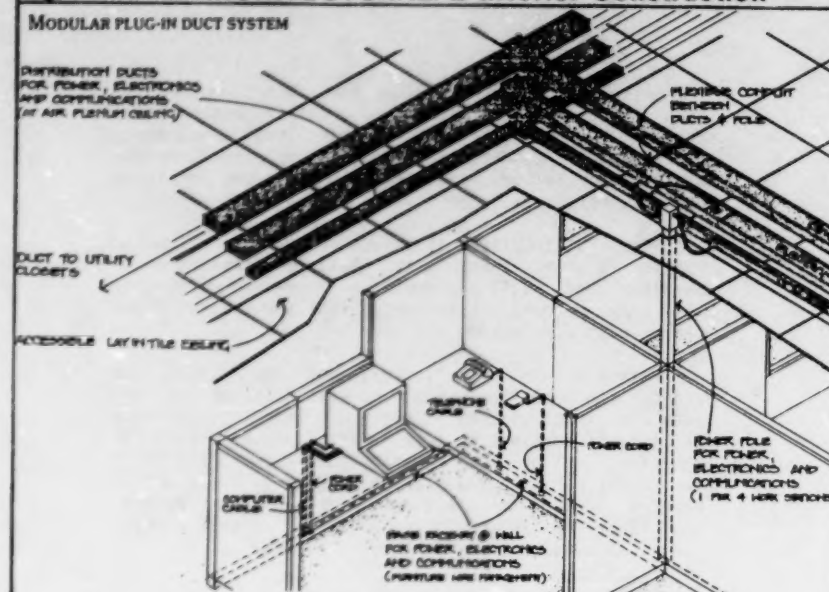
MODULAR PLUG-IN DUCT

Modular plug in duct uses power poles (vertical metal channels typically about 2 inches square) to deliver the power, electronics and communication services from the ceiling to the console or workstation.

The modular plug in duct provides great flexibility in that it can provide the service at any point a power pole can be dropped from the ceiling. The primary objection is that the number of power poles increases with the amount of workstations or equipment placed within the room. In an equipment dense area, the power poles can form a virtual forest of poles which may block views. This is an especially important consideration in that much of the command center decision making process is centered upon the display and viewing of information on walls, boards, or large screen display systems. (200) 14-26

guidance ARCHITECTURAL/2 Interior Construction

MODULAR PLUG-IN DUCT SYSTEM



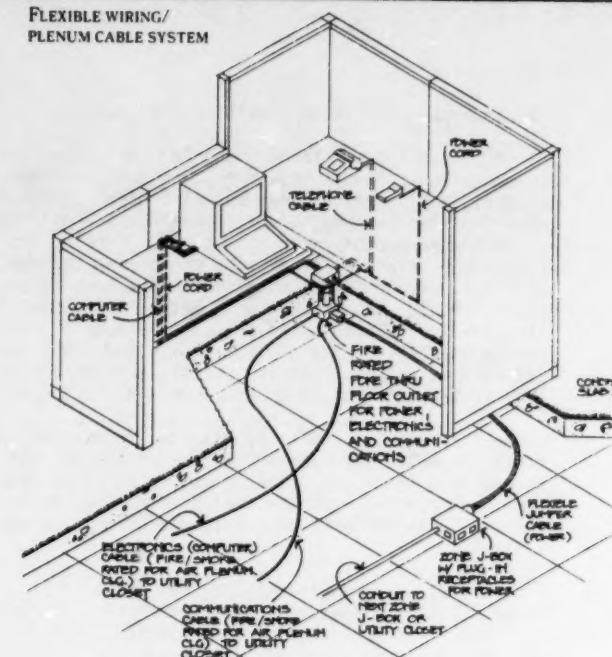
FLEXIBLE PLUG-IN WIRING

Flexible plug-in wiring is fast and easy to install. The name comes from the conduit in which the power is distributed, which is easily bent or twisted. The inexpensive and widely available components include plug-in receptacles for power and lighting circuits, distribution and junction boxes, adapter assemblies and switching modules. Cable sets should be coordinated with both lighting and equipment suppliers.

The use of flexible wiring is limited to power supply and lighting. Electronics and communication must be supplied through other means such as an access floor, enclosed raceway system or a plenum cable. The most serious limitation of the flexible wiring is that the temptation to keep stringing the plug sets together. A frequent consequence is circuit overload, excessive voltage drop or the tripping of a circuit breaker. The search for the problem area, because it may be concealed within a plenum, may be time-consuming and expensive. In addition, while first costs for installation are relatively low, the costs for additional power feeds or outlets are quite high.

Flexible Plug-in wiring may be an alternative for areas where the arrangement and equipment needs are seen to be fairly stable. (200) 14-26

guidance ARCHITECTURAL/2 Interior Construction

FLEXIBLE WIRING/
PLENUM CABLE SYSTEM

CELLULAR FLOOR

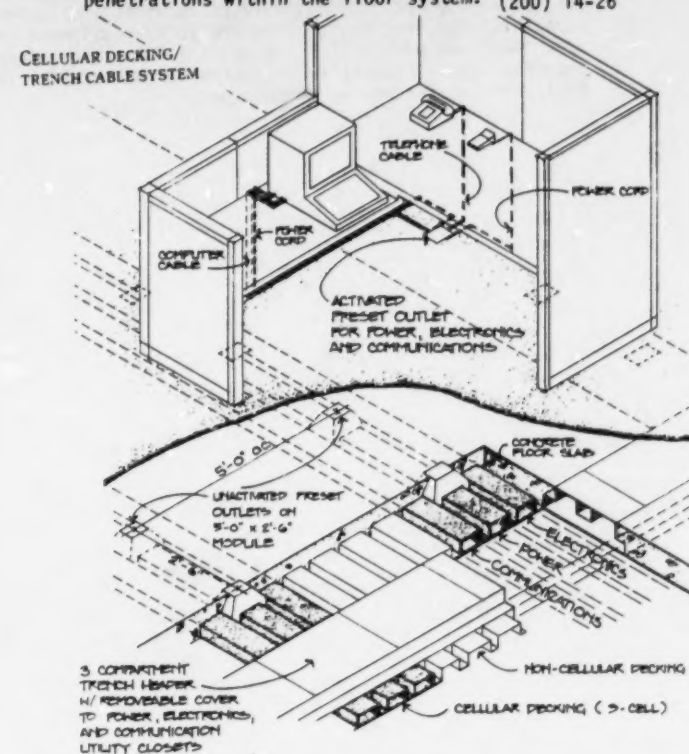
Cellular Floor systems were designed primarily for use in steel frame construction. It consists of structural steel decking that is an integral part of the composite floor slab which distributes the power, electronics and communication services. A metal channel, called a trench header, connects the individual cells and is installed flush with the finished floor slab.

The raceways are usually set at 5 feet on center, with the outlets being placed on a specific preset module, typically 5 feet by 2 1/2 feet. The delivery of power, electronics and communication services is effectively limited to the locations of the preset boxes or distribution points. Outlets which are installed in the preset boxes may be either recessed or flush with the finished floor.

The flexibility of this system is dependent upon the spacing of the preset boxes. It is best to locate them as close together as possible. When this is done the relocation cost is fairly low. New outlets in other locations may be installed, but the cost would be significantly higher than when using the preset locations.

guidance ARCHITECTURAL/2 Interior Construction

The Cellular Floor system allows for the complete power, electronics and communication services, it does not, however provide power service for overhead lighting. The use of cellular systems also requires the use of some type of sprayed on fire proofing material to be applied to the underside of the decking in order to attain the proper rating for the assembly. Finally, the use of the Cellular Floor system is doubtful in those portions of the Command Center requiring EMP/HEMP, and TEMPEST shielding due to the penetrations within the floor system. (200) 14-26



UNDERFLOOR DUCT

Underfloor duct consists of enclosed metal raceways in a concrete floor slab. Typically three raceways are used (for power, electronics, and communications) with a three compartment trench header, with a removable

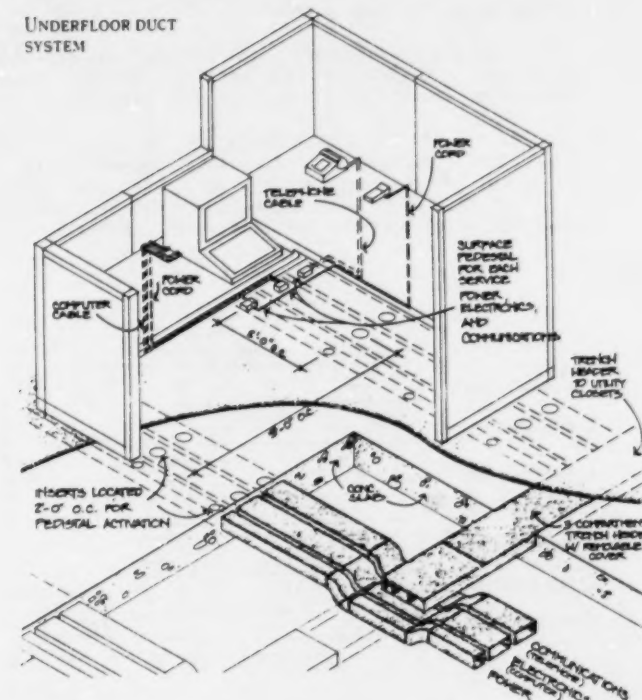
guidance ARCHITECTURAL/2 Interior Construction

cover providing the raceway connections.

Outlet inserts are factory installed on 2 foot centers and are set just below the surface of the slab. Raceways are typically five feet on center.

For installation of an outlet, preset inserts are tapped and a pedestal outlet is installed. Because the system has separate ducts for power, electronics, and communication, one outlet pedestal cannot provide all three services. Single pedestals must be installed for each service which may lead to clutter and potential safety hazards to walking.

Floor pedestals may be abandoned. This work must be done by an electrician who removes the pedestal and replaces it with an abandonment plate. These plates tend to accumulate over the years with changes in furniture and equipment.



guidance ARCHITECTURAL/2 Interior Construction

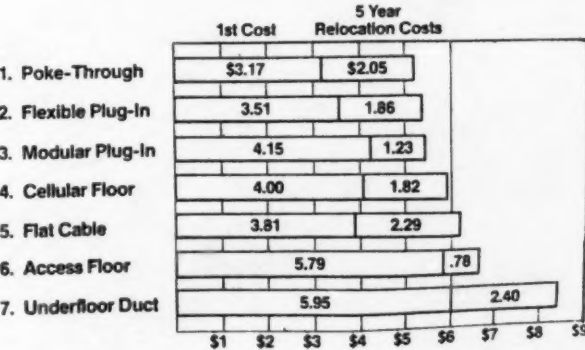
The underfloor duct system is among the most expensive systems to install and also quite high in cost for the relocation of outlets and service distribution points. This along with the use of the awkward pedestal could make the system among the least favorable for a facility such as the command center in which flexibility is such an important issue. (200) 14-26

COMPARATIVE ANALYSIS

The A/E firm of Hammel, Green and Abrahamson in Minneapolis conducted a comparative analysis of the alternative systems which places all six on an equal basis. The study assumes that none of the six systems can be used alone as a single system to satisfy all requirements; all must be supplemented with one or more services to equalize them. Some major conclusions from the study were: (200) 14-26

- 1. All of the major systems, with the exception of underfloor duct are close enough in price to leave room for other considerations such as availability, adaptability to existing structure, and ease of installation, to name a few.
- 2. All of the systems were significantly less expensive when used in conjunction with ceiling lighting, rather than using individual workstation task lighting.

The point of the entire study is to provide some background information to form intelligent decisions with, not to make decisions for you. The Architect and Engineer must along with the owner or client, make the decision which best for the life of the facility.



guidance ARCHITECTURAL/2 Interior Construction

Some comparative cost rankings are presented in this chart, however it should be noted that these costs are for comparison only. They were taken at a certain slice in time, actual costs for a specific installation will depend upon local conditions, the building and the specific power, electronic and communication requirements for a given facility. Further repositioning will be likely to occur as developments are made in both the product and the technology of wire management.

The DCS facility because of its unique requirements for the management of great volumes of wires and cables along with the ever changing nature of the equipment in use, must adopt a policy and develop the system which provides the flexibility necessary to operate in a truly mission responsive environment.

guidance ARCHITECTURAL/2 Interior Construction**d. Interior doors and windows for operations, power and administrative and personnel support spaces****1. Interior doors**

All interior doors (except vault doors) should be equipped with heavy, cylindrical case lock and latch sets. Examples are Series 161, or Series 4000 bored lock and latch sets, Grade 1, which conform with Builders Hardware Manufacturers Association Standard 601. (5) 3-5-10

2. Hinges

All hinges should be of fast pin construction and should conform with Federal Specification FH-H-116. (5) 3-5-10

3. Internal control mechanism

If required for control of routine access, the installation of an electrically controlled and operated latch mechanism for interior doors is authorized. RF emissions should meet the requirements of MIL-STD-461 for Class II-A equipment. Such mechanisms should not be installed to mate or interface with other required locksets. Separate surface-mounted night latches or specialty hardware should be added to doors to accommodate the electrical mechanism. Key-operated bypass cylinders are not authorized. (5) 3-5-10

4. Door closers

All exterior doors and all internal passageway doors (except vault doors) should be equipped with hydraulic door closers in conformance with Federal Specification FF-H-121. (5) 3-5-10

5. Cylinders and keys

All key-operated locks and padlocks used to secure doors or hatches should have an exclusive Government keyway. Primary and secondary entrances should be keyed alike without master keying. All interior doors shall be keyed differently and single-mastered. Key-operated cylinders should use no less than 6 pins, 9 discs or wafers, or 10 levers. Warded locks should not be used. (5) 3-5-11

guidance ARCHITECTURAL/3 Interior Finishes**3. Interior finishes relevant for DCS activities and personnel efficiency**

Flame spread and smoke ratings for interior finishes shall conform to NAVFAC DM-8.

a. Flooring

Operating areas housing electronic equipment

Floors shall be 1/8-inch vinyl tile with a vinyl or rubber tile base. Walls shall be acoustic panels, as shall ceilings in operational electronic spaces.

Storage spaces, vaults, and mechanical equipment rooms

Floors shall be concrete with a dusted-on finish containing hardener; floor hardener must be used on all concrete floors in buildings housing electronic equipment. In general, bases should not be used. When required for protection of wall finishes or for sanitation, however, vinyl or rubber bases shall be used. Walls shall be exposed. Ceilings shall be of exposed concrete or noncombustible, suspended construction.

Offices, corridors, and toilets

Finishes shall be as specified in NAVFAC DM-1.

Other spaces

In UPS spaces and emergency generator rooms, floors shall be concrete with a dusted-on finish containing hardener. Bases shall not be used. In battery rooms, floors and bases shall have an acid-resistant finish. Walls and ceilings shall be exposed.

b. Walls

Paint

Acoustic treatment

Tiles for acoustic treatment should be furnished on the communications room ceiling and walls from the ceiling to 4 feet (1.22 meters) above the finished floor. The exposed face of acoustical tile should have a plastic surface finish. Tiles should be installed as part of the interior finishings. Before installation of the wallboard, the supporting structure for the electrical power panels, convenience outlets, wiring, and ventilation ducts for the air-conditioning system should be installed.

guidance ARCHITECTURAL/4 Special Construction

Acoustical units for wall application shall be metal pan Type V or VII, NRC Grade 70, LR Grade 2, and Pattern a. Units shall be 24 inches square with leveled edges. Facing panels shall be given a two-coat, factory-applied, white, baked enamel finish on exposed surfaces, and at least one coat of factory-applied enamel finish on the back and edges. Sound-absorbing element (pad) of Type V or VII units shall be mineral wool or rock, slag, glass, or a mixture of these. Mineral wool elements shall be enveloped in a flame-proof (class 25) and dustproof wrapper and dustproof facing shall be applied to the element during manufacture.

4. a. RFI shielding (see SB4--"Grounding/Bonding/Shielding" for additional guidance).

1. Wall construction components

2. Roof construction components

b. EMP/HEMP protection (see SB5--"EMP/HEMP Protection" for additional guidance).

1. Wall construction components

2. Roof construction components

c. Building penetration resistance--"Hardening" (See SB7--"Security Systems" for additional guidance).

1. Walls

2. Roofs/floors

3. Doors

4. Windows

5. Utility openings

6. Hardware

d. Vault construction (see SB7--"Security Systems" for vault specifications and penetration resistance).

e. Special protective design (see SB8--"Survivability Protection" for additional guidance).

guidance MECHANICAL/1 Plumbing

1. Plumbing system(s) for DCS facilities

Plumbing systems shall be in accordance with NAVFAC DM-3.1 or equal. Special requirements not covered by DM-3.1 are given below. (92) 12.1-26

Battery rooms

UPS battery rooms and other spaces containing electrolytic solution must be provided with emergency showers and eye washing facilities as specified in OSHA 1926.403. (92) 12.1-226

Shielded enclosures

Domestic water and other plumbing pipes penetrating the shield must be bonded to it to insure RF cutoff. (92) 12.1-26

Sprinkler systems

See SB3--"Fire Protection/Life Safety" for additional guidance.

CBR plumbing systems

See SB8--"Survivability Protection" for additional guidance.

2. a. Outdoor design conditions (19) Vol 2, 6

1. Summer

Critical areas--The 1 percent dry bulb and 1 percent wet bulb temperature conditions should be used for critical areas requiring close tolerance temperature and humidity control. The 2.5 percent dry bulb and 2.5 percent wet bulb temperature conditions should be used for critical areas requiring broad temperature control.

Technical areas--The 2.5 percent dry bulb and mean coincident wet bulb temperature conditions should be used.

2. Winter

Critical areas--The 99 percent dry bulb and average annual mean coincident wet bulb temperature conditions should be used for critical areas requiring humidity control.

Technical areas--The 97.5 percent dry bulb temperature condition should be used.

3. Air-cooled condensers (19) Vol 2, 6

Critical areas--The 1 percent dry bulb temperature plus 5°F (2.8°C) should be used for the summer outdoor design

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condition. The 99 percent dry bulb temperature less 5°F (2.8°C) should be used for the winter outdoor design condition for condenser winterization.

Technical areas--The 1 percent dry bulb temperature should be used for the summer outdoor design condition. The 99 percent dry bulb temperature less 5°F (2.8°C) should be used for the winter outdoor design condition for condenser winterization.

4. Cooling towers and evaporative condensers (19) Vol 2, 6

Critical areas--The 1 percent wet bulb temperature condition should be used.

Technical areas--The 2.5 percent wet bulb temperature condition should be used.

5. Water and glycol coolers (19) Vol 2, 6

Critical areas--The 1 percent dry bulb temperature plus 5°F (2.8°C) should be used for the summer outdoor design condition.

Technical areas--The 1 percent dry bulb temperature should be used for the summer outdoor design condition.

b. Indoor design conditions.

1. Critical areas

Close tolerance temperatures and humidity control--Magnetic units are the communications system components most sensitive to temperature, humidity, and dust. Usually, they can operate within a temperature range of 60° to 80°F (15.6° to 26.7°C) dry bulb and a relative humidity range between 40 and 65 percent. However, the conditions selected within the range must be kept relatively constant. Unless otherwise specified by the electronics equipment supplier, the operating room condition is taken as that temperature and humidity condition measured approximately 5 feet (1.52 meters) over the floor adjacent to the communications system component most sensitive to ambient conditions. One 24-hour temperature and humidity chart recorder should be installed in the same area. Others may be installed elsewhere in the critical area. At present, critical areas of DCS installations using electronic data processing equipment such as AUTODIN are generally held at 73°F (22.8°C) plus or minus 2°F (1.1°C) and a relative humidity of 50 percent plus or minus 5 percent. Usually, this is a safe operating ambient condition for computer rooms. Lower temperatures and humidities would increase operating costs and waste. An operating temperature much above 73°F (22.8°C) might result in an unsafe differential between the operating temperature and the recommended computer shutdown temperature, usually 80°F (26.7°C). The temperature does vary a few degrees throughout

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critical areas, so if the air-conditioning system fails when operating much above 73°F (22.8°C), there may not be enough time to detect rising temperatures and to shut down the computer before damaging temperatures occur at some hot spots in the room. The recommended operating temperature and humidity conditions should be obtained from the manufacturers of the communications and data processing equipment and should be used in designing the environmental control system. (19) Vol 2, 7

Broad tolerance temperature and humidity control--Operational environmental tolerances for installations not using magnetic memory devices or computer equipment are usually quite broad. Generally, AUTOVON equipment can operate within a dry bulb range of 45° to 105°F (7.2° to 40.6°C) and a relative humidity range of 20 to 90 percent. For system design, to assure adequate reserve capacity for safe, reliable operation of the communications equipment, the recommended indoor design conditions for communications facilities not using data processing equipment is 75°F (23.9°C) dry bulb for summer and winter; 50 percent relative humidity for summer; and 20 percent relative humidity for winter. Winter humidification and summer dehumidification should be provided when required. Generally, the air-conditioning system can provide enough dehumidification during the cooling cycle to meet the relative humidity requirements and no supplementary system is required. Very humid climates may require a dehumidification system, however. For operation of installations requiring year-round cooling, the thermostat should be set to the dry bulb temperature currently recommended for comfort cooling based on conservation, economics, and comfort--usually 78° to 80°F (25.6° to 26.7°C). For smaller installations that require winter heating and summer cooling, the thermostat setting for summer should be the same, but the setting for winter should be 68°F (20°C). The humidifier should be able to maintain the minimum relative humidity required to insure that the lower limit of relative humidity is met. At least one temperature and humidity recorder should be installed at a suitable location in the critical area. Recommended temperature and humidity conditions should be obtained from the equipment manufacturer and should be used in designing the environmental control system. (19) Vol 2, 8

2. Technical areas--temperature control

Generally, technical areas such as rooms for support, UPS, battery, back-up power and equipment do not require specific temperature and humidity but have specific high and low temperature limits. Generally, the maximum allowable indoor air temperature is 104°F (40°C) and the maximum is 50°F (10°C), except for battery rooms where the minimum is 60°F (15.6°C). Mechanical ventilation should be used for temperature control as required. In some instances, certain components of technical equipment will require temperatures lower than mechanical ventilation can provide and mechanical

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cooling may be needed. In locations with extremely adverse atmospheric conditions, such as hot, humid, tropical climates, salt-laden marine atmospheres, and atmospheres containing substantial amounts of corrosive, abrasive, or irritating pollutants, consideration should be given to air-conditioning solid-state UPS and battery areas, rather than cooling by mechanical ventilation which usually involves high rates of outdoor air circulation. Recommended temperature limits should be obtained from the equipment manufacturer and should be used in designing the environmental control system. (19) Vol 2, 8

3. Outdoor air ventilation rates and room pressurization

The supply rate of outdoor ventilation air should be high enough to pressurize critical areas to between 0.05 and 0.10 inches of water (12.4 and 24.9 pascal) gage pressure above adjoining areas to prevent the infiltration of unconditioned outdoor air or inadequately conditioned air. The outdoor air supply rate should not be less than 5 cubic feet per minute (2.36×10^{-3} cubic meters per second) per person. Instrumentation should include an indoor-outdoor pressure differential inclined manometer or gage properly installed on an exterior wall inside the critical areas. Battery rooms should be ventilated with nonsparking exhaust fans to maintain a stable room pressure lower than that in adjoining rooms (to prevent the outflow of contaminated air to other rooms). Outdoor air ventilation rates for batteries and equipment should be obtained from the manufacturer and should be used in designing the environmental control system. (19) Vol 2, 8

4. Air cleanliness

The supply air should be filtered for critical areas, technical areas, UPS rooms, and battery rooms. Air filter performance values should be determined in accordance with ASHRAE Standard 52-76. All supply air (outdoor ventilation air and indoor recirculated air) should be filtered with filters that have an atmospheric dust spot efficiency no less than 20 percent. Air should have a minimum average dust weight arrestance of 60 percent. Also, when computers are used, another bank of higher efficiency filters should be installed. For installations using self-contained, specialized computer room air-conditioners, only one bank of the higher efficiency filters should be used for the recirculated room air passing through the units. The final filter efficiency should be as recommended by the computer manufacturer. Generally, efficiency requirements for the final filters depend on the type of magnetic memory units. At most existing AUTODIN switching facilities and some other DCS facilities that use computers, the final filters have a minimum initial efficiency of 60 percent. Generally, newer computer rooms require less efficient filters--around 45 percent average efficiency over the filter's service life (between clean and dirty conditions). (19) Vol 2, 9

guidance MECHANICAL/3 Special Mechanical**5. CBR filtering**

The supply air for critical and technical areas should have CBR filtering ability to maintain operation of DCS facilities during hostile actions or stresses. Smoke, dust, bacteria, radioactive particles, toxic warfare gases, and antimaterial agents could prevent personnel and electronic equipment functioning. These contaminants should be removed by filters and the critical areas, technical areas, and their entrances should be pressurized with this filtered air. Filters should remove 99.95 percent of 0.3×10^{-6} m (0.3 micron) average particle size of DOP test smoke and the flow rate of filtered air should be high enough to maintain an overpressure of 0.3 inches of water (74.7 pascal) gage pressure. See SB8 and (19) Vol 2, 9

6. Room air velocity

Because of the cool temperatures prevalent in critical areas, air-flow velocities should be kept to acceptable levels. Wherever possible in critical equipment rooms, the room air velocity should not exceed 50 feet per minute (0.254 meters per second) at a level of 30 to 60 inches (0.76 to 1.52 meters) above the floor where personnel are seated during normal working conditions and 70 feet per minute (0.356 meters per second) throughout the rest of the occupied zones.

7. Sound level

The maximum allowable ambient sound level caused by the air-conditioning system in critical areas should be 50 decibels (A-rated). The ambient sound level is defined as the unoccupied space noise level with the air-conditioning system operating and the communications equipment shut down. Measurements should be made on the A scale of a standard sound level meter that meets American National Standards Institute (ANSI) Standard S1.4, used according to the manufacturer's instructions. (19) Vol 2, 9

3. Special mechanical**a. Heating systems**

The heating system for the primary air-conditioning system should provide the total installation heating load capacity. The heating system for the secondary air-conditioning system should provide the heating load capacity needed for critical areas to remain operational. The system is generally required to provide heat for technical and office areas, winter humidification, and reheat for summer dehumidification. Heating systems are normally hot water or steam type, with hot water or electric coils normally used for reheat. Steam is normally used for humidification. (19) Vol 2, 12

Central heating plants--At installations for which a central heating plant supplies steam or high-temperature hot

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water is available as a heat source, this source should be considered for the primary heating system. Heat exchangers and converters should be used as required. For the secondary heating system, an individual steam or hot water boiler with required heat exchangers and converters should be considered. (19) Vol 2, 12

Individual heating plants--At installations for which central heating plants are not available as a heat source, individual steam or hot water boilers with required heat exchangers and converters should be considered for both the primary and secondary heating systems. (19) Vol 2, 12

Heating fuels--Conventional heating fuels should be selected based on the availability of supplies, logistics of fuel replenishment, efficiency of operation, availability of O&M personnel, cost of fuels, and vulnerability of fuels. Fuel storage should be based on the most stringent 30-day requirement. (19) Vol 2, 12

Alternative heat sources--Alternatives such as waste heat recovery, thermal storage, and active solar energy should be considered for both the primary and secondary heating systems when feasible. However, a conventional heat source should be provided for reliable backup. (19) Vol 2, 12

b. Refrigeration systems

The refrigeration system for primary air-conditioning should provide the total installation cooling load capacity. The refrigeration system for the secondary air-conditioning system should provide cooling load capacity needed for critical areas to remain operational. (19) Vol 2, 12

Chilled water systems--A minimum of two water chillers should be provided for installations requiring both primary and secondary refrigeration systems. Each system should have a separate water chiller, condenser, and chilled water pumping equipment. Refrigerant compressors and condensers should have enough properly sized controls for the size and type of units selected. Standby chilled water pumps should be provided. At installations for which a central cooling plant supplies chilled water, this source should be considered for the primary cooling system. (19) Vol 2, 12

Direct expansion systems--A minimum of two refrigerant compressors and two condensers or two condensing units should be provided for installations requiring both primary and secondary refrigeration systems. Refrigerant compressors and condensers should have enough properly sized controls for the size and type of units selected. (19) Vol 2, 13

Unitary packaged air-conditioning units--When unitary packaged self-contained air-conditioning units are selected, a minimum of two units should be provided for installations

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requiring both primary and secondary refrigeration systems. The units should have controls available for the size and type of units selected. (19) 2, 13

c. Air-handling systems

The air-handling system provides the conditioned air necessary for the installation to maintain the environmental conditions required. The system normally consists of air-handling units to condition the air and an air-distribution system to deliver the conditioned air. (19) Vol 2, 13

Air-handling units--Normally heat, cool, ventilate, filter, humidify, dehumidify, and supply air to the installation to maintain the desired environmental conditions. They normally consist of a fan section for air delivery, a cooling section, a heating section, a filter section, outside air intake, and exhaust air outlet. A minimum of two air-handling units should be provided for an installation requiring both primary and secondary air-conditioning systems. One unit should provide the total installation air-handling capacity and one unit should provide the critical area air handling capacity. Unitary packaged, self-contained units should be considered for smaller systems. Multiple packaged units or central builtup units providing multiple zone control should be considered for large systems. (19) Vol 2, 13

Outdoor air intakes--Should be located and installed to provide the cleanest source of outside air. Weatherized louvers with bird and insect screens should be used. (19) Vol 2, 13

Exhaust air outlets--Should be located and installed so that exhaust air will not be drawn into the outdoor air intake. Outlets should be weatherized types with backdraft dampers. (19) Vol 2, 13

Air filters--Should be installed in all air-handling units to filter outdoor air and return air before conditioning by the air-handling unit. The filters are normally installed in a special section on the air inlet side of the air-handling unit. The filter sections should have gages installed to measure the pressure drop across the filters. Low-efficiency filters should be the viscous impingement type and may be either disposable or reusable with cleaning. High-efficiency filters should be the dry disposable type. Automatic roll filters should be used whenever the filter bank exceeds 7 feet (2.13 meters) high. All filters should conform to Class 1 or 2 Underwriters Laboratory Standard UL-900.

Electronic air cleaners should not be used because of the danger of charged particles passing through the filter and being attracted to oppositely charged communications equipment. Electronic air cleaner use requires approval by the respective military department, based on the justification provided by the design agency. (19) Vol 2, 13

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CBR filters--A CBR filtering system should be provided to remove contaminants from critical and technical areas. The filtering system should be able to be activated whenever a hostile action or stress begins and to be inactive otherwise. The filtering system should consist of:

- a. Precleaner--dust filter, Federal Specification FF-300.
- b. Particulate filter--Military Specification MIL-F-0051079; removes aerosols and particulate matter, 99.95 percent of DOP that has an average particle size of 0.3×10^{-6} m (0.3 micron).
- c. Gas filter--Military Specification MIL-C-0013724; removes toxic warfare gases.
- d. Air supply blower/fan--provides required air flow through filtering medium.

The filtering system should provide a high enough flow rate of filtered air to compensate for air leakage and outside air ventilation rates while maintaining 0.3 inches of water (74.7 pascal) gage overpressure. Entrance airlocks should be provided to filtered areas; vestibules are a suitable way to accomplish this. The filtering system should either be coupled to the air-handling systems for critical and technical areas or installed separately. For either type installation, the air-handling systems for critical and technical areas must be able to operate at 0 percent outside air upon activation of the CBR filtering system. See SB-8 for further guidance.

Cooling coils--Direct expansion evaporator coils should be used for packaged units and small systems. Chilled water cooling coils should be used with multiple units and larger systems requiring multiple zone control. (19) Vol 2, 14

Heating coils--Hot water or electric heating coils should be used for packaged units and small systems. Hot water or steam heating coils should be used with multiple units and large systems requiring multiple zone control. Hot water and electric coils should be used to reheat for dehumidification. (19) Vol 2, 14

Air distribution systems--Conditioned air from the air-handling units should be delivered to the various spaces or equipment and then returned to the air-handling units through ductwork, diffusers, registers, grilles, ceiling plenums, and floor plenums. The air distribution system should be designed in accordance with the methods and procedures specified in the ASHRAE Guide and Data Book. The correct amount of conditioned air must be delivered to the space, zone, or equipment to insure that communications equipment will be operating within its prescribed environmental conditions. Generally, a single duct, low velocity, constant volume system with terminal reheat is used for critical areas. For technical areas, a constant-volume

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variable-temperature system or a variable-volume constant-temperature system should be considered. The communications equipment operating environmental conditions will normally dictate the type of air distribution system required. (19) Vol 2, 14

Overhead distribution system--An overhead air distribution system should be considered when communications equipment needs negate the requirement for a raised floor. Generally, supply air ductwork should be installed above a dropped acoustical ceiling with the space above this ceiling used as a return air plenum. A ducted return could be used instead of a plenum return. Diffusers, registers, and grilles should be installed at the ceiling or sidewalls. For some types of communications equipment, a ducted supply and return can be connected to the equipment. (19) Vol 2, 15

Underfloor distribution system--An underfloor air distribution system should be considered when communications equipment needs dictate the use of a raised floor. Generally, the space beneath the raised floor is used as a supply air plenum with an overhead ducted return or ceiling plenum return. Supply air diffusers or registers are installed in the raised floor and return air grilles are installed in the ceiling. A positive static pressure of 0.25 inches of water (62.2 pascal) gage must be maintained in the underfloor plenum. A pressure differential gage or manometer should be installed with the raised floor. For some communications equipment, the supply air can be fed directly to the equipment through the raised floor. (19) Vol 2, 15

Ductwork, diffusers, registers, grilles--Ceiling supply air outlets and return air inlets should be readily relocatable without major alterations. This would be done to vary the air distribution pattern with technical equipment relocations and to eliminate hot spots to maintain uniform temperatures throughout the room. Air supply ducts outside the air-conditioned spaces should be insulated with noncombustible material that has an integral vapor barrier. Interior duct linings should not be installed in air supply ducts serving the technical equipment rooms. Sound attenuators should be used when considered necessary. Each return air duct should be insulated as required, depending on its position relative to the ceiling or roof insulation. Ducts below roof insulation normally will not require insulation; however, ducts installed above ceiling insulation should be insulated. (19) Vol 2, 15

d. Humidification systems

A humidification system should be provided for both the primary and secondary air-conditioning systems. These systems should be direct steam injection or heated pan type. Atomizing humidifiers should not be used due to the mineral dust problem. Generally, steam grid systems are used in large air-handling systems and the heated pan type with electric, or hot water coils are used in smaller air-handling units, such as

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those for unitary packaged air conditioning. Humidification systems should provide the relative humidity levels required. (19) Vol 2, 15

e. Economizer air cycle

An economizer air cycle should be considered for all air-conditioning systems when outside weather conditions dictate. These cycles allow the air-handling units to supply up to 100 percent outside air and can reduce the refrigeration load when the outside air can be used for cooling. They can also provide emergency temperature control to some degree should the refrigeration equipment fail. Economizer air cycles are ideal for temperature control; they can be used to control both temperature and humidity provided enthalpy controls are used to prevent high humidity levels. Economizer air cycle use requires approval of the respective military department, based on the justification provided by the design agency. (19) Vol 2, 16

f. Controls and instrumentation

Generally, computer room air-conditioning units are factory-equipped with a complete set of automatic controls, such as operating mode lighted signal systems. When other types of air-conditioning systems are installed, a complete automatic control system with manual override supervisory controls should be included. Adjustable controllers should be provided for regulating temperature and humidity, as well as ambient pressure for some types of installations. Automatic controls with manual override should be included for switchover to secondary systems when such an operation is required. Adequate thermometers and pressure and draft gages should be installed at the proper points to facilitate convenient system monitoring. In addition, enough thermometer wells, gage tappings, and ports should be provided for checking and adjusting the equipment. For central systems, a complete central control gage and alarm panel should be installed in the mechanical equipment room. In addition, an alarm panel should be installed in one technical operations room that has 24-hour occupancy. The central control panel should have a single audible alarm, individual equipment indicating lights, gages, and an associated pushbutton station. The alarm panel should include audible and visual alarms, responding to temperature and humidity sensors located in the conditioned areas to alert operating personnel when extremes of allowable operating ranges are being approached. Also, both alarms should indicate failure of the battery room fan, if applicable. (19) Vol 2, 16

g. Energy conservation

Operating economy and energy conservation are highly desirable, but these goals are secondary to electronic system reliability. When energy monitoring and control systems already exist or are scheduled for installation, consideration should be given to their use, provided HVAC system complexity is not

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increased at the expense of reliability. The following guidelines should be used.

- a. Base the minimum outside ventilation air-flow rate for air-conditioned areas on the average expected building occupancy rather than on a simple percentage of total air circulated. When occupancy will vary considerably, an oxygen and carbon dioxide sensor system should be considered for keeping outside air ventilation rates at the minimum required level.
- b. Avoid conflict between components in the systems, such as excessive latent cooling that must be offset with humidification, or excessive sensible cooling that must be offset with reheat.
- c. Avoid conflict or cross-control between units when multiple units are used, as in computer rooms.
- d. Use capacity increments for improved part-load performance.
- e. Practices such as economizer cycles (except as backup), night setback, and wide-throttling-range or dual-setpoint thermostats are incompatible with electronic equipment spaces that require close control.
- f. For areas not containing electronic equipment, use proper zoning to permit economizers, night setback, and other energy conservation options. (92) 12.1-20
- g. The Naval Civil Engineering Laboratory (NCEL) recommends a five-step plan to save energy. First, determine the present energy consumption patterns in the buildings, the building and equipment characteristics, the condition of the equipment, and the occupants' needs. Second, identify energy conservation opportunities. Third, select and rank the feasible opportunities. Fourth, develop an energy conservation plan, and, fifth, implement it. (164) 224

h. UPS

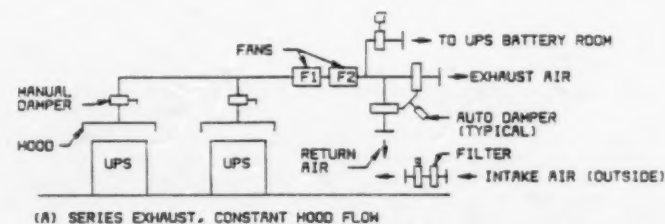
The inside design condition for heating and cooling is 90°F (32°C), which will prevent equipment damage by moisture in the most humid climate. The waste heat generated by transmitters can be used to maintain an elevated room temperature year-round. Air-conditioning is provided only if excessive salt spray, sand, or dust makes it impractical to remove waste heat by ventilation, or if outside design conditions exceed the equipment rating more than 1 percent of the time. Since commercial equipment, as supplied by the General Services Administration, is rated for operation in an environment of 104°F (40°C), and equipment supplied by the Navy is normally rated for 122°F (50°C), air-conditioning is seldom necessary. When air-conditioning is required, year-round levels less than 90°F (32°C) are acceptable, provided a relative humidity of 50 + 10 percent can be maintained without significant reheat.

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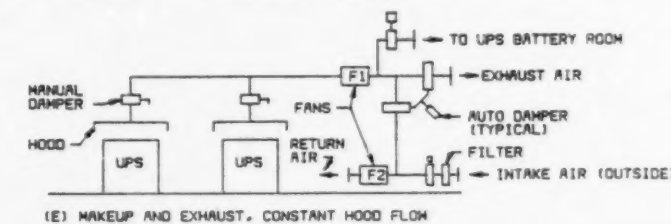
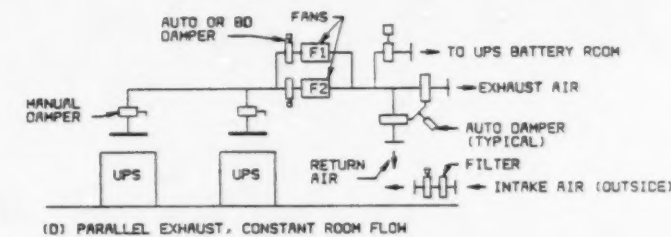
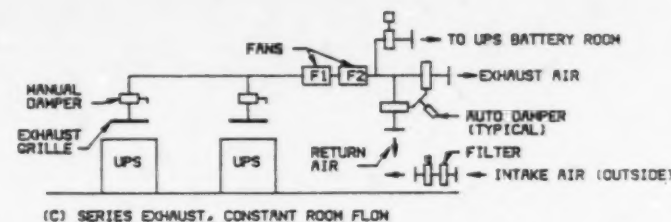
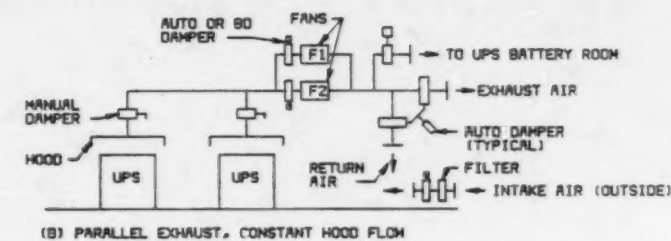
These rooms normally are heated and ventilated only. The inside design condition for heating is 65°F (18°C). There is no inside design condition for summer ventilation.

UPS equipment rooms (92) 12.1-21--The next two figures show several approaches to heating and ventilating these areas. The approaches also apply to naval transmitter buildings, except that transmitters do not require backup heating and ventilation.

Fans--Each fan should be designed to handle the air exhausted through the equipment cabinet plus about 10 percent. In the series arrangement, fans normally should operate with one on the utility circuit and the other on the UPS circuit. Failure of either (as sensed by a differential static pressure switch) should cause a visual and audible alarm. Both fans should have nonoverloading horsepower, such as that possible with air-foil blades, and fairly steep cubic foot per minute-versus-static pressure performance curves, so that losing one fan will not drastically reduce cooling air flow. In the parallel arrangement, one fan is a standby, with the normally operating fan on the UPS circuit and the standby on the utility power circuit. Fans may be forward-curved, backward-inclined, or air-foil, depending on system cubic foot per minute and static pressure. Failure of the normally operating fan should energize the backup automatically. This arrangement requires more space than the series pattern, is more complicated, and requires low-leakage dampers to prevent short-circuiting. Its advantage is that the "failed" fan can be replaced without taking the system out of service. The push-pull arrangement is a typical example of a system that could be used when the UPS equipment room is served from a remote equipment room. It is a series arrangement in the sense that failure of either fan would still allow some ventilation.



UPS EQUIPMENT ROOM VENTILATION SCHEMES

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VENTILATION SCHEMES (CONT'D)

guidance MECHANICAL/3 Special Mechanical

Hoods--If space is available above the equipment, canopy hoods should be provided, unless the electronic equipment manufacturer requires a direct-ducted connection to the unit. The hoods limit intake air temperature (except for insignificant gains) to a value no higher than outside air temperature (in summer), or to a value determined by the room thermostat setting. Hoods should be approximately 6 inches (152.4 millimeters) larger all around than the cabinet and should extend to within 18 + 6 inches (457.2 + 152.4 millimeters) of it. See the ASHRAE Systems Handbook, for a detailed discussion of exhaust hood design. If space for hoods is not available, exhaust registers should be designed to minimize mixing of unit exhaust and room air.

Ductwork and controls--Exhaust ducts should be routed to minimize mixing of exhaust and makeup air. Modulating dampers should be low-leakage type, and controls should be arranged to maintain a room temperature of 90°F (32°C) by modulating outside, return, and exhaust air dampers in response to the room thermostat. Dampers should "fail" to the maximum outside air (safe) position. In colder climates, the design may be more involved than the schematic diagram implies. In warmer or moderate climates, the design may be simpler. A firestat shall stop the fans on a high-temperature alarm signal. Smoke detectors shall be provided in accordance with NFPA 90A.

Other arrangements--When variations in the illustrated schemes are necessary, the design should provide the same degree of reliability and performance. Automatic switching of normal and standby fans should be avoided, since this will equalize wear and may cause them to fail at the same time. Other approaches for heat recovery may be considered in accordance with NAVFAC DM-3.3 and NAVFAC Interim Design Criteria for Energy Conservation.

Auxiliary heating--UPS equipment rooms require backup heat whenever the equipment is down for maintenance or repair. Electric resistance heaters are preferred, since usage is minimal. The heaters should be sized to maintain a minimum of 60°F (16°C) in the space with the UPS equipment off (winter), and 90°F (32°C), to remain above the highest likely dewpoint (summer), with the ventilation equipment deenergized. (92) 12.1-23

9. Battery rooms (92) 12.1-25

UPS battery room--Batteries used with UPS equipment give off negligible heat when charging, and hydrogen gas buildup is low. Because of their thermal inertia, battery case temperatures tend to float between the daily ambient temperature extremes. Normally, acceptable room temperatures can be maintained by heating and ventilating only.

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Ventilation. The ventilation rate required to prevent hydrogen gas buildup may be calculated as follows:

Given: A 192-cell system rated at 500 kilovolt amperes. Maximum charging rate is 50 amperes per cell. Rate of hydrogen gas release (after charging and while gassing) is 0.016 cubic feet per hour per cell per ampere.

Find: Ventilation in cubic feet per minute (cfm) required to limit hydrogen gas buildup to 2 percent.

$$\text{CFM} = \frac{(192)(50)(0.016)}{(60 \text{ min/hr})(0.02)} = 128 \text{ (say 130) cfm.}$$

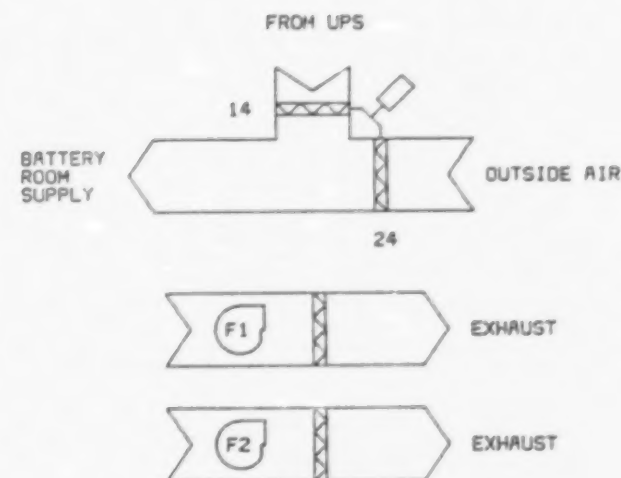
This is a low rate for a room sized to handle 192 battery cells. Therefore, unless specific conditions require otherwise, battery rooms should be exhausted at a minimum rate of six air changes per hour, or about 800 cubic feet per minute, whichever is greater. To provide redundancy, two fans should be used, each sized for half the flow. Fans may be wall-mounted, power roof ventilators, or ducted in-line fans. Makeup air shall be filtered as previously specified. A schematic of the heating and ventilating scheme is shown in the figure below. Fans shall be on the utility power circuit.

Heating. The preferred method of heating UPS battery rooms is a simple ducted arrangement using waste heat from the UPS equipment. (See also the figure below.) Backup heat is required only when the equipment is down for maintenance or repair. Electric resistance unit heaters are preferred. The heater should be on the utility power circuit.

Controls. In the scheme depicted in the figure, the modulating dampers should be controlled in winter by a wall-mounted thermostat set at 65°F (18°C). A switch should make it possible to bypass the thermostat in the summer by fully opening the outside air damper and closing the damper in the branch duct from the UPS equipment exhaust. Dampers should be low-leakage type. Fans should run continuously, except when deenergized by the firestat. Fan failure alarms and hydrogen gas buildup alarms are not required. (92) 12.1-25

Safety features. Battery rooms shall comply with OSHA regulations 1926.403 and 1910.178. (92) 12.1-26

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UPS BATTERY ROOM VENTILATION SCHEME.

guidance ELECTRICAL/1 Electrical Systems

Shielded enclosures--HVAC systems for areas that require electrical or acoustical shielding should be one of two types, as described below.

Electrically shielded enclosures. For these areas, supply and return ducts penetrating the shield shall be provided with RF cutoff cores at the penetration points. Temperature and humidity control sensors shall be located in the return air duct outside the enclosure rather than the space itself. Requirements for backup, inside design temperatures, and similar factors shall be as indicated for the specific facility.

Electrical/acoustical shielded enclosures. Air handlers inside the room should be considered to minimize the size of the fresh air and exhaust ducts that must have acoustic attenuators. Temperature and humidity controls also shall be within the room, and control wires shall not penetrate the shield. This method requires only that power for the fan, plus a few watts for control, penetrate the shield, and therefore, limits the power that must be filtered. The system in the room may use direct expansion, chilled water, steam, or hot water coils in a room air handler with remote heating and refrigeration units. The advantage is that main power for condensing need not enter the room, eliminating the need to filter it. Pipes penetrating the shield must be metallic, bonded to the shield, and long enough to insure RF cutoff. (92) 12.1-26

Vapor barriers--Vapor barriers are especially important for installations requiring humidity control. Effective vapor barriers should be installed on interior walls, floors, ceilings, or roofs. Windows should not be installed in exterior walls of rooms requiring humidity control. Air ducts, utility conduits, cables, and pipes penetrating humidity controlled areas should be vapor-sealed. All doors and passages providing access to and egress from humidity controlled areas should be vapor-sealed. Vestibules should be provided for entrance and exit to all humidity-controlled areas. (19) Vol 2, 11

1.a. Electrical power

Power systems shall be engineered to provide continuity of vital communications. The availability/reliability of the power system shall be based on the communication systems' operational requirements. Minimum electrical design requirements and performance parameters shall be in accordance with MIL-HDBK-411. (2) 5-31

Equipment technical design load

Actual power characteristics at a given site depend on factors such as the type of equipment, amount of equipment, loading of high-powered transmitters, and type and size of support facilities (mess hall, barracks, guard post, outside floodlights, etc.). In addition to equipment, the

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noncritical utility and support-power requirements must be added. (87) Vol 2, 65

Suggested minimum electrical performance parameters for DCS power subsystem

Voltage. Standard three-phase, four-wire voltages should be as follows: (19) Vol 1, 11

Subsystem voltage	Tolerance (percent)
120/208 V	+10
277/408 V	+10
2.4/4.16 kV	+10

Frequency. The standard frequency is 60 hertz. Many types of electronic equipment and subsystems are designed to operate at 50 to 60 hertz. When 50 hertz primary power is available, conversion to 60 hertz is required only for frequency-sensitive electronic equipment. The steady-state frequency tolerance should not exceed ± 0.5 percent of system design frequency. (19) Vol 1, 12

Power factor. The power system shall be able to provide service to a connected load with a power factor of at least 80 percent. The power factor shall comply with DOD 4270.1-M and correction shall be made if the load power factor is less than 90 percent at rated load. Fluorescent lighting devices shall have a minimum power factor of 95 percent. (19) Vol 1, 12

Availability. The primary and auxiliary power supplies and the distribution system shall be engineered to provide 99.99 percent availability (exclusive of scheduled outages) to the technical load bus(es). (19) Vol 1, 12

Mean time between failure (MTBF) and mean time between overhaul (MTBO). Realizing that MTBF and MTBO vary with each type of equipment, they shall be specified individually for each power source. For DOD standard generator sets, the MTBF and MTBO are as specified in MIL-STD-633. (19) Vol 1, 12

Steady-state stability. Power systems should be designed to limit the short-term steady-state voltage stability to ± 2.0 percent of the system design voltage and to ± 0.5 percent of the system design frequency at any load from maximum to minimum steady-state station loads. For commercial power, the steady-state regulation should be evaluated in terms of operational impact and regulating devices provided as required. (19) Vol 1, 12

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Dynamic or transient variation. Power systems should be designed to limit the dynamic or transient variation of primary power to the following limits: the maximum transient variation of the voltage delivered to the operational load bus should be within -20 percent and +10 percent of the system nominal voltage and the frequency should be within ± 3.3 percent of the system nominal frequency. The duration of these transients should not exceed 500 milliseconds. In cases for which primary power interruptions or severe transients are appreciably worse than these limits, the primary power system should be investigated to determine corrective action required to meet operational requirements of the system to be served. (19) Vol 1, 12

Complex operating schemes shall be avoided. Switching operations may be either manual or automatic, but should be as simple as possible. Positive checks should be included to reduce the possibility of error to a minimum. (19) Vol 1, 7

Power protection

The primary power should disconnect automatically when the voltage or frequency exceeds the following limits. (6) 22

Voltage--120/208 volts ± 10 percent for a period greater than 1 minute.

Frequency--50/60 hertz ± 15 hertz for a period greater than 1 minute.

Voltage--120/208 volts ± 20 percent for any period.

Frequency--50/60 hertz ± 10 percent for any period.

The undervoltage control coils in the input circuit breakers can be used to meet this disconnect requirement. Restoration of power service to the load after an interruption for an out-of-tolerance condition shall be manual. (23) 10

Standby power

The function of auxiliary power is to provide power for operation during interruption or extended degradation of primary power. All auxiliary generating power facilities should be designed for current load requirements. The electronics and support load requirements are expected to continue to decrease as microelectronics influence the design of electronic and communication equipment. Therefore, to conserve energy and maintain high operating efficiency, an auxiliary power source should be selected that will operate near rated capacity. (19) Vol 1, 12

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STANDARD FREQUENCY AND VOLTAGES BY COUNTRY. (188)22-16,22-17

COUNTRY	Frequency (Hz)	Secondary Systems (Volts)
Belgium	50	127/220,220/380
Germany	50	220/380
Greece	50	220/380
Italy	50	220/380
Japan	50,60	100/200
Korea	60	100/200
Luxemburg	50	220/380
Netherlands	50	220/380
Okinawa	60	120/240
Panama	60	110/200
Turkey	50	220/380
United Kingdom	50	230/400,240/415
United States	60	120/208,277/480

DOD STANDARD FAMILY GENERATOR CHARACTERISTICS (1) 33

Kilowatts	Freq (hertz)	Type engine	No. 0	MTBF (hours)	Classification type/class	pf	MEP model no.
60	50/60	Diesel	3	500	I/2	0.8	006A
60	50/60	Diesel	3	500	I/1	0.8	105A
60	400	Diesel	3	500	I/1	0.8	115A
60	400	Gas turbine	3	1500	I/2	0.8	404A
83.3/100	50/60	Diesel	3	500	I/2	0.8	007B
83.3/100	50/60	Diesel	3	500	I/1	0.8	106B
100	400	Diesel	3	500	I/1	0.8	116B
167/200	50/60	Diesel	3	500	I/2	0.8	009A
167/200	50/60	Diesel	3	500	I/1	0.8	108A
417/500	50/60	Diesel	3	500	I/2	0.8	011A
417/500	50/60	Diesel	3	500	I/2	0.8	029A
625/750	50/60	Diesel	3	1500	I/2	0.8	409A
625/750	50/60	Diesel	3	1200	I/2	0.8	208A

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CLASSES OF ELECTRICAL POWER (87) 11-67

Power class	Operational power requirement	Characteristics
Primary power class A	Includes all utility, technical and critical technical operational loads resulting in a steady-state operational requirement.	Steady-state power, subject to various voltage and frequency deviations, transients, and occasional complete power failure.
Auxiliary power, class B	Same as class A; capable of indefinite operation; should have 15 days' fuel supply available. Auto system operational at -10% or +10% voltage variation after 5-sec delay. Covers extended outages that may last for days.	Supplement to primary power. Subject to complete loss of synchronized power for approximately 20 sec during automatic power transfer after primary power loss.
Auxiliary power, class C	Provides auto-start power plant to provide rapid restoration of power to the technical load. Starts on voltage variation of +3.3% with an adjustable time delay of approximately 5 sec. Minimum fuel supply of 7 days. Covers outages of relatively short periods (hours).	Supplement to primary power. Assumes load in shortest practicable time after failure of primary power (10 to 60 sec).
Uninterruptible power system (UPS) and no- break power, class D	Provides continuous uninterruptible power and prevents the occurrence of transients and surges on the critical technical load.	Automatically assumes load when required and automatically shifts load back when primary power becomes available. No power interruption, and minimum voltage and frequency deviations.

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The standby electrical power plant shall include at least three diesel-engine-driven generator sets, a motor-generator set (MG), a solid-state UPS, fuel and cooling systems, and all necessary switch gear and control devices to provide a reliable, stable, operable power plant. All generators shall be of identical size and type, and from the same manufacturer.

The diesel generators shall be designed for Class B service (AFM 88-15 and MIL-HDBK-411) and shall be rated such that any two units can carry the entire station load on a continuous basis. The plant shall be designed for two units online (sharing the load), and one unit on standby duty. Accordingly, upon interruption of either or both primary power supplies, at least two preselected generators shall start automatically, synchronize, and parallel automatically as required. These two generators shall then assume the station load automatically. In the event one of the preselected units fails to start or fails while running, the standby unit (unless locked out) shall automatically start and take the place of the failed unit. Return to primary power and shutdown can be manual; however, the system shall be designed such that return to primary power supplies will not cause a system outage. This will require that the generators synchronize and parallel with the primary power supply. The power plant shall be designed to provide reliability no less than 99.99 percent exclusive of scheduled outage. Dummy loads shall be provided when powering up generators for off-line testing.

A power plant status panel and alarm shall be provided in the EMSC area. The purpose of this system is to indicate power system conditions for operating personnel. The status panel shall indicate information such as primary power availability, standby generators running, UPS condition, and motor-generator online. Audible alarm positions and indicating lamps and test shall be suitable for indicating status changes or failure of major systems.

Class B auxiliary power--A standby long-term auxiliary power plant may be required if multiple commercial power feeders are not available or feasible to provide power, or if extended, frequent power outages may result from natural causes or sabotage. The criteria for a class B plant are comparable to those for a primary power plant, except that only one spare generator set is required. Class B plants must be able to operate between 1000 and 4000 hours annually. The fuel storage amount should be determined by local replenishment conditions and should provide at least a 15-day supply. Since the construction cost of a class B plant approaches that of a primary power plant of equal size, the decision to provide a power installation requiring class B service should be made only after careful study. The class B unit may be started by an automatic control system. The autostart control system should be adjusted to start the prime mover when the primary

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power voltage varies more than -10 percent or +10 percent or the frequency changes more than an adjustable time delay of approximately 5 seconds. The engines should be equipped with coolant preheaters to facilitate rapid start and load assumption. An alarm indicating such action should be sounded in the area where personnel responsible for manning the plant are stationed. The plant may be connected to the load automatically when practical, and removed from the load manually by synchronizing and then paralleling with restored primary power, disconnecting electrically, and shutting down. (19) Vol 1, 13

Class C auxiliary power--The function of an autostart power plant is to restore power rapidly to the technical load. When practical, the nontechnical load should be served temporarily from the class C plant. Use of more than 1 unit on the split bus is recommended where the technical load exceeds 300 kilowatts at 120/208 volts or 600 kilowatts at 277/480 volts. Spare class C units shall be provided for rotational maintenance and overhaul if justified. The prime movers for these units should have ancillary equipment to assure that the load is assumed in the shortest practical time (for example, if liquid-cooled diesel engines are used, they should be equipped with jacket water heaters and circulators and could use lube oil heaters to insure quick starting). The fuel storage amount should be determined by local replenishment conditions, climate, and geography, and should provide at least a 7-day supply. The autostart control system should be adjusted to start the prime mover when the primary power voltage varies more than -10 percent or +10 percent or the frequency changes more than +3.3 percent after an adjustable time delay of approximately 5 seconds, or as otherwise dictated by operational requirements. Maximum use shall be made of the established DOD Standard Family of Mobile Electric Power Generating Sources defined in the current series of Military Standard MIL-STD-633. MIL-STD-1332 provides the definitions of tactical, prime, precise, and utility terminology for selecting the required class of DOD generators. (19) Vol 1, 13

Off-line load banks--Off-line load banks should be provided to facilitate testing of auxiliary generators and UPS as outlined in DCAC 350-195-2. This provision will circumvent the need to obtain access to the station load for test and exercise requirements and permit the auxiliary power system to be tested without degradation. (19) Vol 1, 13

guidance ELECTRICAL/1 Electrical Systems**System voltage and frequency tolerances**

1. Tolerances. The voltages should be within ± 5 percent of the rated voltage.
2. Steady-state variations of the incoming primary power supply should not exceed $+1$ percent of the design voltage and $+0.5$ percent of the design frequency (60 hertz) at any load from the maximum to the minimum steady-state station load. If steady-state voltage variations can be expected to exceed $+5$ percent, appropriate voltage regulation of the supply feeders will be required.
3. Class B powerplant generator units should be started by an automatic control system. The autostart control system should be adjusted to start with the prime mover when the incoming primary power voltage varies more than -10 percent and $+10$ percent or the frequency changes more than ± 3.3 percent after an adjustable delay of approximately 5 sec. The voltage sensing relays should be capable of -20 percent adjustment.
4. Voltage regulators should be provided on the supply feeder to maintain the voltage regulation of the incoming supply at ± 5 percent. Voltage regulation should be accomplished by automatic tap-changing-under-load regulators. Voltage regulators should be of three-phase, step type, and shall be installed to regulate the incoming supply bus voltage. Bypass disconnecting switches should be installed in the regulator circuits in order to permit inspection and repairs without prolonged interruption of electric service to the facilities.
5. Distribution system. Dual feeder circuit breakers and redundant feeders should be provided for all long-haul communications systems (i.e., long-range communications) in accordance with AFM 88-15, Chapter 23 and power distribution system diagram Atch 2. Single feeder service is acceptable to all other systems.

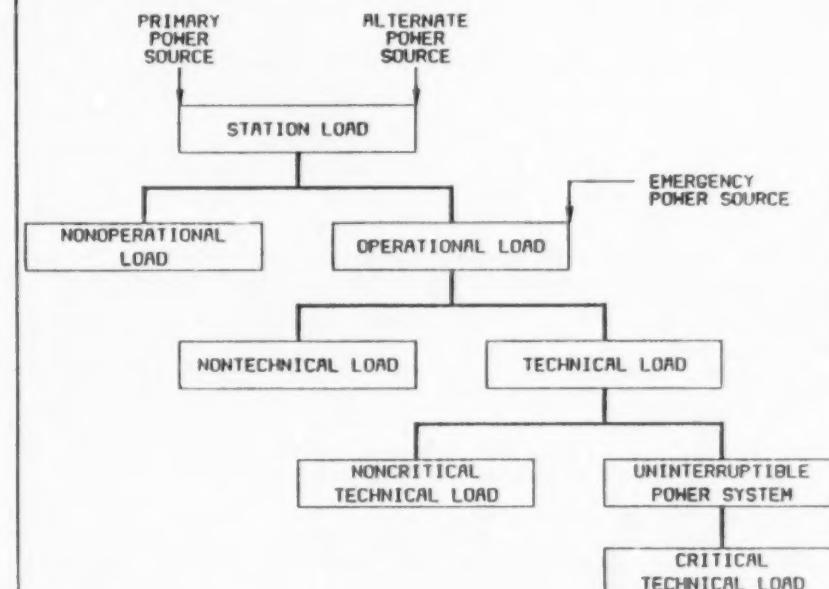
Load categories

Electronic facility power loads are divided into categories according to function and allowable downtime. The load categories are defined as follows: (92) 12.1-29

1. Station load. The total power requirement of the electronic facility.
2. Nonoperational load. Administrative, support, and miscellaneous power requirements not essential to facility operation.

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3. Operational load. That portion of the load required to keep the facility in continuous operation. (The sum of the technical and nontechnical loads.)
4. Nontechnical load. That part of the total operational load used for general lighting, convenience outlets, air-conditioning, ventilating equipment, and other functions for normal operation. Several hours of downtime may be permitted.
5. Technical load. That portion of the operational load required for electronic equipment and ancillary equipment, including the lighting, air-conditioning, and ventilation required for full continuity of facility function. The operation of the technical load is essential to the mission of the facility.
6. Noncritical technical load. That portion of the technical load not required for synchronous operation. This includes nonsynchronous electronic equipment, test equipment, emergency lighting, ventilation, and air-conditioning for electronic equipment. An outage of up to 2 minutes may be tolerated.



DCA CIRCULAR 300-95-1

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7. Critical technical load. That part of the total technical load required for continuous synchronous operation of electronic equipment. This includes any equipment that will malfunction during a momentary power dropout and cause additional outage after power is restored, as a result of the need to resynchronize; loss of real time count by master time sources; or loss of data in ADP systems.

Government-furnished UPS equipment shall serve all critical technical loads. The BESEP will specify the loads to be served by the UPS, as well as the size of the system.

Electrical distribution

The primary power distribution system shall be designed for the types of electrical loads shown. The loads shall be segregated and duplex facilities such as transformers, feeders, and circuit breakers are considered necessary to provide the reliability and maintenance ability required for critical communications loads. Underground feeders should be used to enhance reliability and to avoid interference with the communications facility. The distribution system should include the standard protective relays such as those for overvoltage, overcurrent, and reverse power whenever the primary and auxiliary power systems are designed to operate in parallel. (19) Vol 1, 11.

- Each load category shall be fed as described below.
- Separate circuit breakers shall be provided at power panels for each equipment rack, cabinet, or piece of electronic equipment. Individual pieces of equipment shall be connected to the panelboards by wiring run in cable racks or conduits or a combination of both. Bolt-on circuit breakers should be used in electronic facilities.
- Most buildings require underground radiofrequency cable, communication cable (telephone type), control cable, and power cable. These cables shall enter the building through two cable vaults, one for signal cables and one for power cables. These vaults shall also house the protective devices used to prevent surges from entering the building. The vaults shall be designed in accordance with the latest safety standards.
- Wiring to each piece of equipment shall be sized to carry full load current. Maximum voltage drop shall be in accordance with the NEC.
- All receptacles other than 120-volt, general-purpose convenience outlets shall be marked with voltage, amperage, phase, and frequency.
- Full-size neutral conductors shall be used throughout the distribution system.

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- Cableways. Cable shall be routed through trays or ducts suspended overhead. When raised flooring is used, cable shall be run in conduit within the space under the floor in accordance with the requirements of NEC.
- Bus ducts may be used as required.
- When more than one building is fed from a common transformer, the neutral and the green ground wires shall be bonded together and grounded at the secondary side of the transformer only. No ground shall be provided at the first disconnect.

OVERHEAD OPEN RACK VERSUS FLOOR TRENCH--
DISTRIBUTION COMPARISON (70) 15-15

Type distribution	Advantages	Disadvantages
Overhead open rack	Flexibility in arrangement and rearrangement of cables Rapid, economical installation of racks and cables Cable expansion accommodated readily	Time-consuming for cable installation Difficult to maintain clean, neat appearance Separate racks required for signal and power cables
Floor trench	Rapid, economical installation of cable Provides neat, clean appearance	Equipment arrangement dictated by trench layout Cable expansion limited by trench size Extremely difficult to separate power and signal cables

guidance ELECTRICAL/1 Electrical Systems**Power distribution panels**

Power for the technical equipment shall be provided at 208/120-volt, 3-phase, 4-wire, 50 or 60 hertz. Regulation, as measured at the technical equipment power panels, shall meet the following requirements:

Voltage--208/120 volts ± 10 percent.

Frequency--50 or 60 hertz ± 5 percent.

Voltage balance--Line-to-neutral voltages shall not deviate from nominal by more than ± 2.0 percent for any balanced load that varies from 0 to 100 percent unbalanced loads.

Harmonic distortion--Total harmonic distortion shall not exceed 5.0 percent. No single harmonic shall exceed 3.0 percent.

Phase displacement--Shall not exceed ± 1.0 degrees for balanced loads or ± 5.0 degrees for 50 percent unbalanced loads.

The equipment will interface with the building power distribution system at power panel boards installed in each technical equipment room. The technical power panel boards shall be equipped with circuit breakers. (23) 10

Since most all communication facilities have electronic equipment added at future DCS expansions, initial power panel boards should be oversized by two times to accommodate new circuits. This will prevent the wide dispersal of panel boards over time.

Distribution interference

Auxiliary equipment such as air-conditioning, ventilating systems, and pumps containing motor drives are inherent transient creators, particularly under starting conditions. This equipment should therefore be electrically isolated from electronic equipment to the degree required to avoid adversely affecting the communications-electronics (C-E) equipment operation. In no case should the transient producing, motor driven equipment be served from the same distribution panel as sensitive C-E equipment. (19) Vol 1, 7

Attention should be given to both radiated and conducted forms of interference, plant layout, and cable shielding and routing. (19) Vol 2, 11

At electronic facilities, it is possible for classified information from processing devices to be coupled inductively into power lines; consequently, power distribution conductors entering areas where classified information is processed may

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need to be filtered at the area boundary. Specific guidance concerning the treatment of such power and signal cabling will be contained in the BESEP. In general, primary power distribution and protection should be outside classified areas to facilitate access for maintenance. Normal power distribution design for electronic equipment areas requires consideration of the peculiarities of communication and electronic equipment. For example, low-level signals in the microvolt range and a large frequency spectral environment would suggest that power lines be routed as far away as possible from the nearest antenna. Radiofrequency noise sources such as generators, air-conditioning compressors, and switchgear should be located to minimize physical and electrical interference with electronic equipment. Voltage transient protection should be installed on both transient sources and power distribution points for electronic equipment. Commercial power conditioning equipment containing instrumentation and alarm capabilities, as well as active and passive protection devices, may be necessary to provide the quality of power suited to the equipment being supported. (92) 12.1-32

Power system status panel

A power status panel with suitable meters and alarms should be provided in the control area of each operating building to indicate voltage and frequency delivered to the critical technical loads. Audible and visual alarms should be provided on the panel to function when controls have initiated starting of the auxiliary power units. Additional alarms should be provided to indicate the malfunction of unattended auxiliary power units. An automatic or manual alarm acknowledgment should be provided to inhibit audio alarms once the operator knows an alarm condition exists. (19) Vol 1, 9

Protective devices and safety

Feeders and branch circuits should have circuit protective devices coordinated to insure disconnection of the faulted circuit as close to the fault as practical. Guarding of live parts and protective devices shall be installed and identified in accordance with the safety requirements of the National Electrical Code. Grounding shall conform to the standards set forth in MIL-STD-188-124. Transient protectors, such as metal oxide varistors (MOV), should be installed to protect transient-sensitive equipment. For low-voltage power distribution, three basic ratings of MOVs (Series L, Series PA, and Series HE) are available and are designated in the order of increasing joules. Series PA is recommended for low-voltage power distribution feeders and Series L for installation in branch circuit panel boards. (19) Vol 1, 8

guidance ELECTRICAL/2 Special Electrical Systems**2. Special electrical systems****a. Protection of equipment**

Sensing equipment shall be supplied by the local site on the incoming power systems. Provisions shall be made to automatically disconnect the primary power when the voltage or frequency exceeds the limits as specified in (6) 22

b. Protection of communication signal

Auxiliary equipment such as air-conditioning, ventilating systems, and pumps containing motor drives are inherent transient creators, particularly under starting conditions. This equipment should be electrically isolated from electronic equipment to the degree required to avoid adversely affecting the C-E equipment operation. In no case should the transient producing, motor driven equipment be served from the same distribution panel as sensitive C-E equipment. (19) Vol 1, 7

c. Power and voltage (see also "Protection of equipment" above)

Most equipment requires a +24 VDC supply rectified from single phase 50 to 60 hertz 115 VAC commercial source or supplied directly from an alternate energy source. The +24 VDC main supply is distributed throughout the equipment room and regulated down to proper device voltages in the equipment. (7) Vol 1, II-46

Foreign power--Equipment and facilities to be operated in foreign countries shall be designed with the power characteristics just described. If frequency conversion is required because of foreign power characteristics, a synchronous generator shall be used. The input requirements and output capacity should be determined by the power available and the requirements of the equipment to be connected. Consideration should be given to standby requirements and location of the frequency conversion equipment. Generally, the frequency conversion equipment should be as close as feasible to the equipment being served. (92) 12.1-31

400-Hertz power--Electronic facilities often require that power be supplied to equipment at a frequency of 400 hertz. Two types of frequency conversion equipment are available: motor generators and static converters. The type and capacity of the units should be determined by the equipment's requirements. Consideration should be given to standby requirements when selecting and locating frequency converters. Both types of converters must be grounded adequately to prevent electromagnetic interference. Power at 400 hertz requires conductors larger than those required for 60 hertz. To determine the proper wire size, calculate the size of conductor required on either a d.c. or a 60-hertz system, then increase the size one AWG unit. All

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cables carrying 400-hertz power shall be run in separate raceway systems. For further information, refer to NAVFAC DM-4.5. (92) 12.1-32

Direct-current power systems--Electronic facilities often require several d.c. power supplies and distribution systems. The systems usually operate at 24 or 40 volts. (92) 12.1-32

d. Emergency status

The C-E equipment will require full power. Task lighting can be reduced to 65 percent of normal in operations areas; ambient lighting in other areas can be reduced to 20 fc, and HVAC equipment must maintain the temperature in C-E equipment spaces within the limits of its operating range. (7) Vol 1, II-47

e. Division of circuit loads

During initial installation of electronic systems, or when additional equipment is added, the primary power load division must be considered. Indiscriminant loading of power panels can result in: (42) 16-2

Poor voltage regulation

Circuit breakers dropping out when multiple equipment is used simultaneously

Overheating of circuit breakers

Group loop problems (when phases are unbalanced, neutral currents proportional to the unbalance will flow).

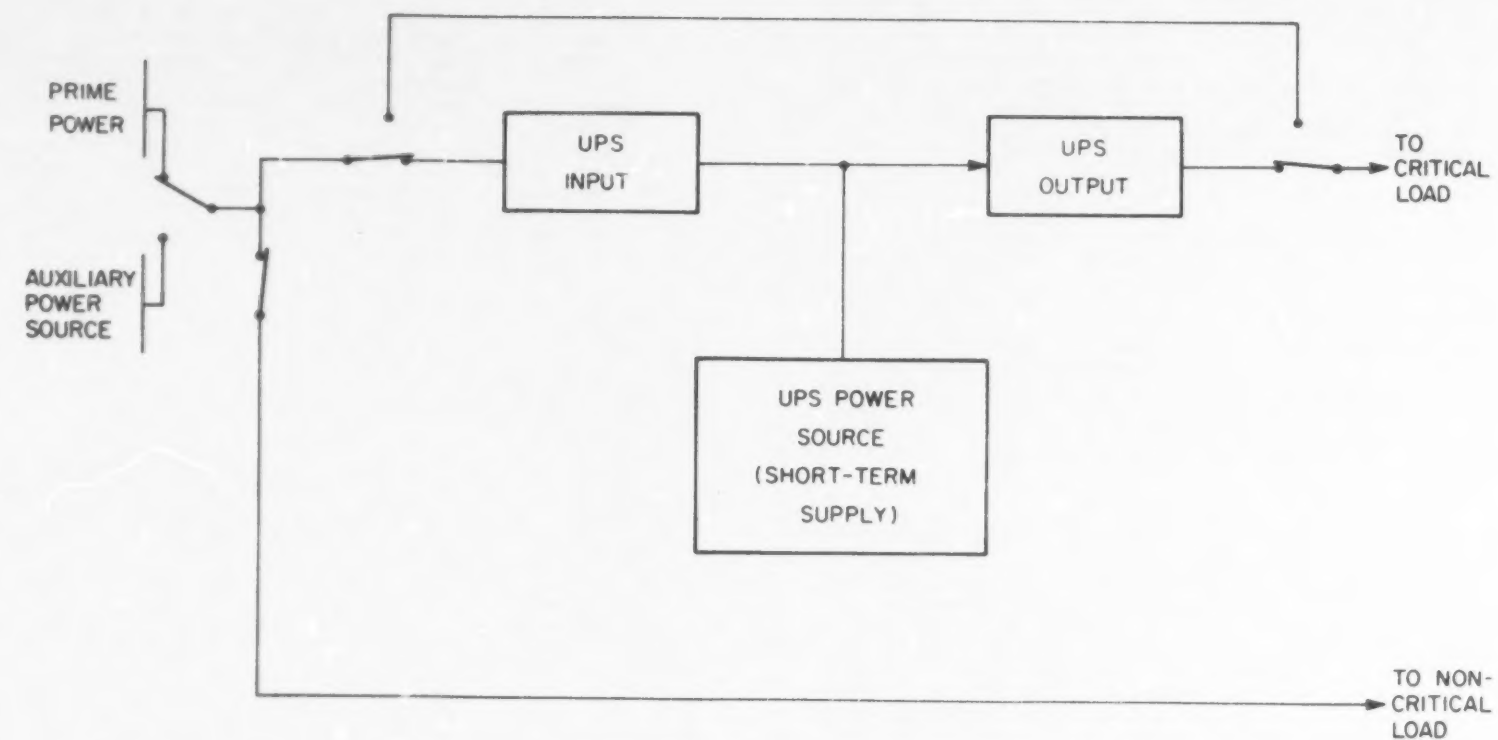
f. Plugs and receptacles shall be the polarized grounding type. Plugs for double-insulated equipment need not be grounded. All 120-volt, single-phase, 15- and 20-ampere receptacles installed outdoors or in other wet locations shall be provided with ground fault circuit protection. (42) 16-6

Plugs and power cables for 120-volt, single-phase equipment should conform to MIL-C-28777. (42) 16-6

In an installation for which various voltages, frequencies, or numbers of phases are used, a different receptacle type is required for each combination. All receptacles, except convenience outlets, should have a nameplate attached that states voltage, phase, and frequency. (42) 16-6

All three-phase receptacles should be wired to produce clockwise phase rotation viewed from the front, and the nameplate should so state. (42) 16-6

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BASIC UPS CONFIGURATION.
(1) 151

guidance ELECTRICAL/2 Special Electrical Systems

g. Uninterruptible power system (UPS) and batteries

Introduction--The configuration of a basic UPS is shown in the figure below. During normal station operation, the UPS will be supplied with a.c. power by the primary power source--the UPS then changes the a.c. power into a storable d.c. electrical energy to be used as a short-term, no-break power supply for critical equipment. The UPS uses only a small amount of energy to maintain the energy storage levels. The rest is reconverted into a.c. electrical energy. The a.c. power input and output of the UPS are isolated from each other by the energy storage medium. A way should be provided to bypass the UPS completely in the event of failure or maintenance. When possible, the UPS shall be located outside the operations room, preferably with the other power equipment. The four common types of installed UPS are described below. (1) 150

Flywheel-motor-generator UPS. This type of unit can provide uninterruptible power only for very short periods and should be considered only when the auxiliary power source can assume the station load within 1 minute. The flywheel-motor-generator UPS consists of an a.c. electric motor-generator unit with a flywheel as the energy storage device. The primary a.c. power source provides power for an a.c. induction drive motor, which provides rotary power to an a.c. generator and steel flywheel. When the primary power source is interrupted, the potential energy stored in the flywheel continues to provide rotary power for the a.c. generator. (1) 150

Rotary uninterruptible power supply. The rotary uninterruptible power supply (RUPS) has the same components as the flywheel-motor-generator UPS, plus an engine and eddy current clutch. When the primary source is interrupted, the flywheel provides rotary energy for the a.c. generator as before; in addition, the sensing and control equipment operates the eddy current clutch, which connects the drive engine to the flywheel shaft. The rotary energy of the flywheel starts the drive engine, which then provides rotary drive power for the flywheel and a.c. generator. The RUPS will continue to provide critical power as long as the engine remains running. (1) 150

Electronic uninterruptible power supply. The electronic uninterruptible power supply, or EUPS (see figure), consists of one or more a.c.-to-d.c. rectifier-chargers, an external battery bank, one or more inverters, and a static switch. The incoming prime a.c. power is changed into d.c. power by the rectifier-charger(s). The d.c. power is used to charge and maintain a large battery bank at float voltage and to provide power to the electronic inverter(s). The output of the inverter(s) consists of a series of d.c. voltage steps, which are filtered to

guidance ELECTRICAL/2 Special Electrical Systems

approximate a sine wave. A static switch provides fast electronic switching to bypass the UPS in case of inverter failure or extreme load variations. The EUPS normally can provide uninterruptible power for 15 to 30 minutes at full load. (1) 150

Hybrid uninterruptible power supply. The hybrid uninterruptible power supply (HUPS) is used at overseas AUTODIN switching centers (ASC). HUPS consists of a redundant solid-state rectifier-charger, a float battery, and one or more motor-generator sets with associated controls. The rectifier-charger converts three-phase primary or standby input power to d.c. to supply the d.c. motors that drive the a.c. generators. The rectifier-charger also supplies charging current to the float battery. Upon primary power failure, the battery bank provides d.c. power to the d.c. drive motors for about 15 minutes. In the following discussions of reliability and input-output quality, HUPS has the input advantages and disadvantages of the EUPS and the output advantages and disadvantages of the RUPS. (1) 150

UPS reliability--A modern solid-state UPS is a reliable source of conditioned power. The UPS is usually provided with an electronically controlled static bypass switch for which input and output frequencies are identical. The static switch permits automatic bypass if the UPS fails. Also, a manual bypass switch often is provided to permit maintenance on any part of the total UPS system. (1) 153

UPS output quality--All types of UPS typically provide a very high quality of sine wave output (when properly loaded). The output unit is either a filtered inverter or a synchronous generator that can generally provide an output quality equivalent to commercial power; however, the UPS output quality is very dependent on the characteristics of the load served. Frequently the load consists of rectifier inputs serving electronic power supplies that can create significant distortion of the UPS output waveform. Nevertheless, the UPS output total distortion should be no more than 5 percent. (1) 153

UPS input distortion--The EUPS usually uses a silicon-controlled rectifier-charger as the input unit, which can cause large spikes on the input waveform. The input power to the EUPS should be filtered to limit total distortion to 5 percent at the supplying circuit breaker. (1) 153

Noise and environmental considerations--Acoustically, the engine-drive RUPS is the noisiest type of UPS. It should be located with the auxiliary generator equipment or onsite in a separate building away from the station operating equipment areas. The EUPS is also electrically noisy, as voltage spikes can be induced onto the EUPS equipment cabinets and all metalwork that contacts the cabinets; the EUPS metalwork should therefore be electrically isolated from the satellite earth station equipment, with the exception of the fault ground connection to the main station

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electrical ground point. The EUPS should not require environmental controls to maintain temperatures and humidity levels, but ventilation for EUPS and batteries will be required. When large additional power transformers are used with the EUPS, these should be located outside to minimize the heat load. (1) 153

A UPS should serve the critical technical load. The UPS should be solid-state with batteries able to support 125 percent of the critical technical load for a minimum of 15 minutes. The UPS is designed to protect equipment from voltage and frequency disturbances inherent on conventional power distribution systems. The UPS must maintain output voltage and frequency, regardless of the nature or severity of incoming line fluctuations or changes in load.

The UPS should operate in conjunction with the existing power distribution system to provide quality power for critical technical loads. The system should consist of a solid-state inverter, a battery charger/rectifier, storage batteries, and a static transfer switch with bypass switch, as described later.

Modes of operation

Normal--The inverter should supply critical load continuously. The battery charger should derive power from the utility a.c. source and should supply d.c. power to the inverter while simultaneously float charging the battery.

Emergency--Upon failure of the utility a.c. power, the critical load shall be supplied by the inverter which, without any switching, should obtain its power from the storage battery. There should be no interruption to the critical load upon failure or restoration of the utility a.c. source.

Recharge--Upon restoration of the utility a.c. source, the rectifier/charger should power the inverter and simultaneously recharge the battery. This shall be an automatic function and should cause no interruption to the critical load.

Bypass--For maintenance, the UPS should be supplied with a static switch which should transfer the load to the alternative source without an interruption. The static switch should be provided as a drawout assembly so the complete UPS or the static switch can be electrically isolated for maintenance once the load has been transferred to the alternate source. The load should be retransferred by automatically synchronizing the UPS to the alternative source, paralleling the inverter with the alternative source and allowing it to ramp into the load, and then disconnecting the alternative source. A bypass switch should be incorporated into the system to allow the UPS to be removed from service.

Downgrade--If the battery only is taken out of service for maintenance, it should be disconnected from the rectifier/charger and inverter with a circuit breaker. The UPS

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should continue to function and meet all the performance criteria specified herein except for the reserve time ability.

General requirements

Semiconductor fusing--All power semiconductor circuits should be fused to prevent cascaded or sequential semiconductor failures. Indicator lamps denoting blown fuse conditions should be provided.

Components--All active electronic devices should be solid-state. All semiconductor devices should be sealed. Vacuum tubes should not be used. All relays should be provided with dust covers.

Noise--Noise generated by the UPS under normal operation should not exceed a sound pressure level of 75 decibels (A) measured 6 feet from the UPS surface. Decibel reference pressure is 0.0002 dynes per square centimeter.

Grounding--The UPS output a.c. neutral should be electrically isolated from the UPS chassis. The UPS chassis and signal ground systems should be connected together and to a common ground point. The UPS output a.c. neutral bus will be connected to the power neutral ground bus in the facility.

Wiring--Wiring practices, materials, and coding shall be in accordance with the requirements of National Electric Code NFPA 70 and other applicable standards.

Materials--All materials and parts comprising the UPS should be new, of current manufacture, and should not have been in prior service except as required during factory testing.

EMI suppression--Electromagnetic effects should be minimized to insure that computer systems or other electronic equipment shall neither adversely affect nor be adversely affected by the UPS.

Surge protection--The UPS shall have built-in protection against undervoltage, overcurrent, and overvoltage, including lightning surges introduced on the primary a.c. source and voltage and current surges on the output caused by load transfer between itself and an external synchronized source. These should be automatic functions requiring no manual adjustments.

Printed circuit board interlocks--All plug-in printed circuit boards should have mechanical interlocks to prevent a board from being plugged into the wrong place. Electric interlocks should be included to prevent system operation if all boards are not installed properly.

Flexibility--The UPS initially being furnished as a nonredundant system should have provisions for all necessary interface connections and accessory items to insure it can be

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easily and economically expanded in the future for increased capacity or to provide a fully redundant solid-state UPS.

System efficiency--The overall efficiency, input to output, should be measured with the battery fully charged and the inverter supplying full rated load. The manufacturer should guarantee system efficiency in the proposal.

Control panel--A system control panel containing meters, controls, and indicators should be furnished. All status indicators should use light-emitting diodes for long life. The control panel should have at least the following complement of meters, controls, and indicators:

Meters (2% panel type)

a.c. input voltage	a.c. output voltage
a.c. input current	a.c. output current
Battery current (zero-center)	d.c. voltmeter
Elapsed time	

Controls

a.c. output breaker	a.c. output voltage adjust
UPS module on	Alarm unstore
UPS module off	Lamp test
Input current limit adjust	Horn silence
d.c. voltage adjust	Transfer to bypass

Status indicators

a.c. input breaker open	UPS module OK
a.c. input breaker closed	UPS module alarm
d.c. battery breaker open	UPS module tripped
d.c. battery breaker closed	Sync to utility
a.c. output breaker open	Voltage difference
a.c. output breaker closed	System bypass breaker open
UPS module on	System bypass breaker closed
UPS module off	

Alarm indicators

Charger fuse blown	Power supply failure
Charger logic failure	Load division trouble
Charger overtemperature	d.c. undervoltage trip
Battery ground	d.c. overvoltage trip
Battery discharge	Inverter leg failure
Battery undervoltage	a.c. undervoltage trip
Inverter fuse blown	a.c. overvoltage trip
Inverter overtemperature	Frequency control failure
Inverter output overload	Power sync trip
Fan failure Signal sync trip	
Capacitor fuse blown	Static switch failure
Oscillator failure	

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Rectifier/charger--The rectifier/charger should be solid-state with constant voltage/constant current control circuitry.

Input. The rectifier/charger input voltage and current should operate within +10 to 15 percent of nominal voltage without causing the battery bus voltage to drop below the battery open circuit voltage. This should be an automatic function requiring no manual adjustments.

Voltage regulation. The rectifier/charger output voltage should not deviate by more than ± 1 percent due to the following conditions:

No load to 100 percent load variation on UPS system

Primary input voltage variations up to ± 10 percent

Ambient temperature, range 0°C to +40°C.

Current limit. The rectifier/charger should be able to supply an overload current no less than 125 percent of full load current (FLC). For greater output currents, the rectifier shall be current-limited. Upon removal of the overload condition, the rectifier/charger should return to normal with no degradation of performance or components. The input current limit should be adjustable over the range 100 to 125 percent of full load input under nominal operating conditions.

Logic and control functions should be provided to enable switching the current limit between two present levels, to be controlled by external form "C" contacts. This function permits fast recharge of the battery when utility power is available and reduces the current demand when input power to the charger is being provided by standby generators.

Input harmonic suppression. The rectifier/charger should be designed to limit the input harmonic current feedback into the source to a maximum of 10 percent total harmonic distortion (THD) with nominal input voltage and rated load on inverter.

Power transformer. A dry type isolation transformer should be provided for the a.c. input to the rectifier/charger.

Walk-in. The rectifier/charger should contain a timed walk-in circuit that causes the unit to assume the load gradually after the input voltage is applied. The initial magnetizing inrush surge should be limited to 600 percent of the rectifier/charger FLC.

Power factor. The rectifier/charger should have a minimum power factor 0.9 with nominal input voltage and frequency and the inverter operating at rated load.

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Overload protection and disconnect. Input circuit breaker and output fuses should be provided for rectifier/charger disconnect and overload protection. The overload devices should not be activated when the rectifier/charger is started under any of the operating conditions listed.

Capacity. The rectifier/charger should have enough capacity to support a fully loaded inverter and recharge the battery to 95 percent of its fully capacity within 12 times the discharge time.

Inverter--Should be a step-type that generates three-phase a.c. power. It should be able to provide the specified quality output power while operating from any source voltage within the battery operating range. The inverter output voltage and capacity should be in accordance with the attached system data sheet and should meet the following conditions:

Voltage regulation. The inverter steady-state voltage should not deviate by more than ± 1 percent due to --

0 to 100 percent load

Ambient temperature variations

Minimum to maximum d.c. bus voltage.

The inverter voltage shall remain within the steady-state band for the following:

Inverter "drop" onto battery with full rated load on its output.

Retransfer of rated load from the alternative source to the inverter.

Frequency regulation. The inverter free-running, steady-state output frequency should not deviate by more than ± 0.1 percent due to --

0 to 100 percent load

Ambient temperature variations

Minimum to maximum d.c. bus voltage.

The inverter output should have zero frequency transients for the system disturbances listed under voltage transients.

Harmonic distortion. The inverter should provide harmonic neutralization and filtering necessary to limit harmonic distortion in the output voltage to less than 5 percent and single harmonics to 3 percent over the entire load range.

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Voltage adjustment. The inverter should have a control to manually adjust the output voltage ± 5 percent from the rated value.

Frequency control. The output frequency of the inverter should be controlled by an oscillator that can be operated as a free-running unit or as a slave for synchronized operation with a separate a.c. source or the future redundant inverter. The inverter should track the synchronizing source within ± 2 degrees. If the external synchronizing source deviates from the preset frequency by ± 1 hertz, the oscillator should automatically revert to free-running.

Load sharing. The inverter should be capable of load sharing with the redundant inverter to be installed in the future. This should be possible without the use of master controls, oscillators, or sharing reactors.

Line drop compensation. The inverter should be provided with circuitry such that output voltage rises linearly with output current. The rise should be adjustable from 0 to 5 percent. No external voltage sensing should be required to achieve this function; also, the function should not interfere with other requirements of this specification. This feature should compensate for varying line drop voltage between the inverter and the critical load.

Static switch with bypass--A static switch bypass should be provided as an integral part of the UPS inverter section. The control unit should contain an automatic transfer circuit that senses the status of inverter logic signals and alarm conditions to provide an uninterrupted make-before-break load transfer to the alternative source. This should be done without exceeding the transient limits specified here when a malfunction occurs in the UPS. The status switch should be drawout for easy maintenance and should be completely removable during bypass operations with no interruption to the critical load.

Static switch. The static switch should be naturally commutated to reduce component count and insure maximum reliability. The bypass static switch should be paralleled with a motor operated circuit breaker, which is activated simultaneously with the static switch for positive connection of the load to the alternative source. It should not be dependent on internal UPS logic or control level power supplies.

Bypass. A circuit breaker should be incorporated into the static switch section of the UPS, which shall allow complete electrical isolation of the UPS and static switch for maintenance.

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Operation. The static bypass switch should include as a minimum the following features:

(a) The static bypass switch should automatically transfer to the bypass source upon detection of an inverter failure.

(b) Upon repair of the UPS, the critical load should be retransferred the UPS. The UPS should automatically walk-up smoothly and assume the critical bus in a "bumpless" way before disconnection of the bypass source, which also should be automatically sequenced (make-before-break).

(c) In the unlikely event of multiple transfer-retransfer, the UPS should limit the "cycling" to three transfer-retransfers in any 10-minute period. The load will be locked to the bypass source on the fourth transfer and should require manual reset to return to automatic operation.

(d) To further increase critical bus reliability, the UPS should transfer to the bypass source if an over/undervoltage condition occurs on the critical bus. This should be an automatic feature and act as a redundant backup to the automatic bypass transfer in case of an incipient failure/trip of the UPS.

(e) A manually initiated make-before-break bypass should be provided for routine maintenance. This bypass should be automatically inhibited if the bypass source is outside voltage or frequency limits or is not properly synchronized with the critical load bus.

Battery bank--This should be used as a stored energy source for the UPS. The battery's ampere-hour rating should be high enough to support the inverter for the protection time specified with the inverter operating at rated load. The battery parameters should be in accordance with the input voltage requirements of the inverter section.

Construction. The battery should be sealed, assembled in heat-resistant, shock-absorbing clear plastic containers with covers cemented in place to form a permanent leak-proof seal. Covers should be fitted with explosion-resistant vent caps. Cell post and cover should be sealed against electrolyte creepage either by burned-ring seals or by lead-alloy seal nuts. Cell terminal posts should be equipped with connector bolts that have acid resisting nuts. Enough sediment space should be provided so that the battery will not have to be cleaned out during its normal life. Electrolyte level lines shall be marked on all four sides of the container.

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Racks. A suitable galvanized steel rack should be furnished. Lead-plated copper interrack connectors and cell numbers should be provided. Plastic covers should be provided to insulate the rails and the cells. Racks should have two coats of acid resistant paint.

Ground protection. The battery should have a high-resistance ground and a ground detection alarm for maximum personnel safety; this will be an integral part of the UPS.

Diagnostics--The logic section of the inverter should include a built-in simulator to allow a complete check of SCR logic performance without energizing the power circuits.

Mechanical design

Ventilation--Forced air cooling should be provided to insure that all components are operated within their environmental ratings. Blower motors should be equipped with sealed bearings. Each enclosure should have redundant blowers, and blower unit failures should set off an alarm. All air inlets should be equipped with standard type filters, replaceable from outside the unit. All air inlet and exhaust openings should be protected with expanded metal guards.

Modular construction--The UPS solid-state power switching circuits and control systems should be modular in construction for easy maintenance and for minimizing down time. The modules should be grouped by function, with interchangeability between modules that have the same function.

Power switching modules--All solid-state power switching modules shall be drawout type, removable from the front of the UPS. The weight should be kept to a minimum to allow removal by one person without the aid of lifting devices.

Parts placement--The UPS should be designed to permit ready access to modules and assemblies. Parts, test points, and terminals should be placed such that they are accessible for circuit checking adjustment and maintenance without the removal of adjacent modules or assemblies.

Power connections--All power connections should be bolted type for reliability. The connections should include conical (or Belleville) washers and anti-Galvanic corrosion joint compound to insure long-term integrity.

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h. Cable tray

A cable tray system shall be provided to support interrack cables and waveguide runs. This system shall be mounted at a height of 8 feet above the finished floor. Cable trays over GSC-39 shall be 9 inches wide with a nominal loading depth of 3 inches (Cope 3-3538-09SL-12-06 or equivalent). This cable tray shall be supported so that it can carry a cable loading of 40 pounds per linear foot. Cable trays over DCSS racks shall be 18 inches wide and shall support 70 pounds per linear foot. The sides and cross members (rungs) shall not have sharp edges or corners that could injure personnel or damage cable assemblies. Openings shall be in walls between transmitter and communications rooms to permit cable tray passage between the rooms. (23) 12

Trays must be able to be removed, added, or rerouted without major structural modifications to the building. (42) 7-3

Because of possible electronic interference in an electrical installation, cable and wire segregation shall be considered during the initial installation layout. Electronic interference is defined as any conducted or radiated electromagnetic disturbance that interferes with the operation of electronic equipment. (42) 7-1

Cable segregation techniques

Metallic ducts are recommended for mobile installations because of their space-saving features. Cables can be segregated in fixed station installations by routing the high-, medium-, or low-level cables in separate wireways or cable trays. When trenches are provided, power and control cables are installed in them and RF and audio cables are installed in overhead cable trays, if practical. (42) 7-2

The following rules shall be followed as closely as possible when routing cables and wires of different interference classes and levels. (42) 7-2

a. Radar modulator pulse cables are the largest contributors to cable radiation interference. For this reason, modulator pulse cables shall be installed a minimum of 18 inches away from all other cables.

b. Active cables, if at all possible, shall be installed at least 18 inches from passive and susceptible cables. Active cables should also be separated from each other, as a high-power cable can cause conducted interference in a low-power cable. When installing active cables for an antenna, strict adherence to the separation requirements is not always possible.

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c. Passive and susceptible cables should be spaced a minimum of 2 inches apart.

d. When it is impossible to comply with the above rules because of space limitations, physical requirements, or other uncontrollable factors, it is necessary to use shielding. Shielding or segregation is not required when cables cross at a 90 degree angle.

e. Individually shielded pair cables in accordance with specification MIL-C-28781 (EC) shall be used on timing, high-speed data, and high-level control circuits. A good cable installation should fulfill several requirements: cable runs must be as short as possible; cables must be suitably protected from mechanical injury; and cables must be easily accessible for troubleshooting. If possible, room must be left for future expansion. (42) 7-3

Cable fasteners (clamps, etc.) are used to tie down, route, and support cables and wire harnesses by securing them to walls, floors, frames and other structures. Fasteners are also used to provide strain relief at cable/harness connections and terminations. The fasteners are used in addition to the lacing, tubing, and straps used to bundle the harness. Fastener selection and location depends on installation factors such as diameter, weight, and configuration of the cable or harness and the type of supporting structure. Many cable fastening devices are available. This section describes some common types and uses. (42) 7-10

Cable clamps

These are used to mount cables and harnesses to supporting structures and are available in metallic and nonmetallic materials. (42) 7-10

Plastic clamps--Plastic clamps are manufactured in a variety of shapes. Materials such as polypropylene, nylon, Teflon and ethyl cellulose are commonly used in their production.

Reinforcing washers--When required, D-shaped metal washers can be used with plastic clamps to give added strength. One example is where lock washers are used under the screwhead. These washers are made of 22- to 24-gage steel and are available in various corrosion-resistant finishes. They are not supplied as part of the plastic clamp.

Metal clamps--These are generally stronger than plastic clamps, but introduce problems such as corrosion due to

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dissimilar metal contact with support structures. Metal clamps, if used, shall be insulated with rubber or plastic bushing to prevent cutting contact with metallic sheaths.

Clamping pads and bars--These are used in conjunction with binding straps to both bundle and affix the cable bundle to walls, floors and similar places.

Cradle clamps--These are available in a variety of sizes; each size is further adaptable by using different clips. Cradle clamps are fastened to a bulkhead to support wire/harnesses and cable bundles.

Unistrut cable fasteners

These devices are used extensively. Channels shall be installed a maximum of 16 inches apart center-to-center. A greater distance permits sagging of small cables. After the channels are installed, clamps are inserted (clamped) around the cable. The clamps are available in outer diameter sizes from 1/8 to 5/8 inch in increments of 1/8 inch and are made of steel, copper, or aluminum. This same clamp configuration is available in outer diameter sizes from 1/4 to 5/8 inch in increments of 1/8 inch, made of steel, copper, or aluminum. The same configuration is available for rigid-steel and thin-walled conduits. (42) 7-11

Explosive set studs

If a large facility requires numerous anchorings in concrete, the explosive set stud greatly speeds installation. These power-actuated tools must be operated, repaired, serviced, and handled only by personnel who have been trained and certified by the manufacturer or another authorized representative. (42) 7-11

3. a. Lighting--general

Full-range dimming control with switching is required in each room except hallways, latrines, electrical equipment room, mechanical equipment room, and UPS and battery room.

Lights selected should provide easy access for relamping and maintenance. Special attention should be given to lighting for high-bay areas so that these lights can be relamped when necessary.

The height from the floor to the bottom of the fixture should be at least 9 feet or installed to suit the respective rooms'

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ceiling height. The minimum height from floor to lighting fixture in communications rooms and cable vaults should be 13 feet.

All lighting should be designed with consideration given to aesthetics, brightness control, specular reflection, operating costs, and energy conservation.

Rooms infrequently occupied and requiring not more than 20- or 30-footcandles can use incandescent lighting.

Lighting branch circuits should be designed for not more than 80 percent current capacity.

Corridors and administrative areas should have night lighting circuits equal to about 10 percent of normal lighting.

Basic Factors to be Considered in Lighting Design:

The following list contains the basic factors recommended for the design of lighting systems:

General Requirements:

1. Purpose of the interior (activities may be diverse, and more than one lighting scheme may be needed); probable layout of plant, furniture or equipment, where this is known.
2. Availability of daylight: the need to combine electric light and daylight.
3. Extent to which contrast rendering in the task is important: risk of veiling reflections.
4. Degree of modeling required and provision of directional lighting.
5. Color appearance and color rendering required.
6. Task and building illuminances; localized or general lighting; need for optical aids.
7. Requirements for glare control.
8. Statutory requirements or official recommendations.
9. Need for emergency lighting.
10. Presence or absence of hostile environment; need for special luminaires, e.g. flameproof, dust-tight, watertight.
11. Unusually high or low general temperatures, e.g.

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foundries, cold storage; effect on control equipment and luminaire components.

12. Possibility of high ambient temperature near luminaires (e.g. at ceiling level and in stop windows).

13. Possible effect of radiant heat from furnaces or other industrial equipment on luminaires and control equipment.

14. Effect of heat from luminaires on air temperature in interior; use of lighting heat for part of building heating.

Effect of Structural Features:

15. Dimensions of interior: length, width, height.

16. Luminaire mounting height.

17. Luminaire spacing/mounting height ratio.

18. Reflectances of ceiling, walls and floor, including influence of furnishings, windows and glazed partitions.

19. Coordination of lighting equipment with other building services.

20. Limitations on luminaire mounting position (e.g. roof structure, number of bays, modular construction of building, space available in ceiling void).

21. Effects of obstructions by parts of structure (e.g. beams) and other services (e.g. ventilation ducting, pipework).

Lamps:

22. Lamp types which meet color appearance and color rendering requirements for interior activity.

23. Lamp light output related to source size and mounting height.

24. Rationalization of lamp type, color and wattage, particularly with existing installations.

25. Heating up time to full light output and need for standby system to cover any interruptions of power supply.

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26. Need to reduce flicker and stroboscopic effect.

27. Economics-capital and running costs.

Luminaires:

28. Suitability for purpose.

29. Aesthetic appearance.

30. Luminous intensity distribution required.

31. Authenticated photometric data.

32. Need for special equipment.

33. Availability-present and future-of spare parts.

34. Weight; arrangements to hold the luminaire in place.

35. Use of supporting systems or lighting tracks.

Maintenance

36. Maintenance factors.

37. Accessibility of luminaires-need for special equipment.

38. Acceptability of proposed luminaires, lamps, etc. to client's maintenance staff.

SOURCES OF ILLUMINATION:

FLUORESCENT:

- large number of color types permits selective color rendition
- requires ballast
- low initial cost
- long life
- optical control possible with special reflector or lens
- bare lamp has low luminance
- requires special ballast and lamp protection in cold ambients
- ballasts may be noisy
- must be installed to assure correct ballast operation
- dimming of small numbers expensive and troublesome
- complete dimming system effective and energy saving

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- very high efficacy
- medium life
- high initial cost
- pronounced orange color
- 1 to 4 minute start and restart time
- good optical control possible

INCANDESCENT:

- good color rendition except for blues
- inside frosted lamp good for optical control
- greatest variety of lamp shades and bases
- lowest initial cost
- can be easily dimmed
- slight increase in operating voltage above rated voltage will shorten life drastically
- short life and low efficacy results in high owning costs
- radiant heating is noticeable above 85 footcandles

LOW PRESSURE SODIUM VAPOR:

- monochromatic yellow color
- long lamp life
- requires ballast
- highest efficacy

MERCURY VAPOR:

- considered by many to be obsolete
- very long life
- good optical control possible
- ballast required
- may be noisy
- good color rendition with some types
- dimable with special equipment
- low efficacy in smaller sizes
- high initial cost
- takes 3 to 10 minutes for start and restart

METAL HALIDE:

- medium life
- good color rendition with some types, but some color inconsistency
- good optical control possible
- ballast required
- may be noisy
- good efficacy
- 3 to 10 minutes start and restart
- high initial cost
- poor lumen maintenance

TUNGSTEN HALOGEN:

- good color rendition
- excellent for optical control
- luminaires very small

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- easily dimmed
- high initial cost
- short life
- difficult maintenance and low efficacy results in high owning costs
- very little interchangeability of types
- radiant heating is noticeable above 85 footcandles

b. RFI-free fluorescent lighting

This should be provided for all rooms and adjacent hallways except for rooms infrequently occupied. It should comply with the following requirements:

1. RFI-free fluorescent fixtures should be enclosed 2- or 4-lamp, 40-watt, commercial fluorescent type. Fixtures should have no unprotected openings between metal parts. The opening for light emission should be covered with a borosilicate glass that has a permanently bonded transparent electrically conductive coating with a 1/4-inch-wide silver ground-ribbon bonded to the coating along each long edge and fastened to the bare metal of a hinged door frame at two points. The hinged frame also should be bonded to the bare metal of the fixture housing at two points. The coating should have nominal resistance of 50 ohms per square and should shield radiated radio interference to within the limits of the MIL-STD-461. The fixture should have a lumen output equal to or greater than 55 percent of the bare lamp lumens when tested with the electrically conductive glass in place. Each fixture should be connected by a ground wire to earth. The ground wire should be fastened to the bare metal of fixture housing.
2. Transmittance of the electroconductive-coated glass should be no less than 70 percent in any direction, and photometric test data should be gathered.
3. RF suppression line filters should be a double pi-section filter connected in series with the incoming hot line and neutral to the fixture. The filters should be made up of a 200-microhenry inductor and two 0.25-microfarad capacitors with the free end of the capacitors connected to the ground.
4. Fixture should be given production sample tests and reports should be submitted to show that the fixtures meet or exceed the RFI suppression limits established by MIL-STD-461.

guidance ELECTRICAL/3 Lighting**c. Exit lighting**

Exit lights should be placed throughout the building in compliance with NFPA Standard 101. The one exception to the placement of exit lights is that illuminated signs cannot be positioned so that they are within sight of any security surveillance television cameras. The constant lights would burn out the camera's orthicon tube, making it useless. A nonilluminated exit sign may have to be substituted when these conditions exist.

The signs will be surface-mounted, recessed, or stem-mounted as required and will have downlight ability.

The signs will be a self-powered combination with a power pack for each sign.

The standard requirements are as follows:

1. Power pack to be mounted either on top of sign or in a recessed box. The power pack should contain a fully automatic, solid-state charger able to recharge the battery in 24 hours.
2. The power pack will have a test switch and pilot light.
3. The battery should be hermetically sealed lead calcium gel type or equal.
4. Stem-mounted signs should be extended so that they can be readily seen by personnel in the area. (See SB3 for additional guidance.)

d. Emergency lighting

Battery operated, solid-state, emergency lights should be used throughout the facility and should be equal to or exceed OSHA and NEC standards. These lights will activate automatically if a power failure occurs. Equipment should meet the following requirements:

1. A 120-volt a.c., 60-cycle input operation with a test switch light capability and trickle charge for battery.
2. Solid-state charger rated at .001 to 10 amps as battery requires, based on electrochemical impedance, voltage, and electrolyte conductivity.
3. The battery should be lead acid or nickel cadmium rechargeable, designed specifically for emergency lighting. The battery is to have a transparent container and a disc float hydrometer with a rating of 100 ampere hours.

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4. Two lampheads should be fully adjustable vertically and horizontally. The lamps will be the sealed beam type with a 25-watt nominal rating.

5. Capacity in watts, to 87.5 percent per NEC will be rated at:

1.5 hr	2 hr	4 hr	5 hr	8 hr
245	198	114	99	66

with a full 1.5-hour battery capacity.

e. Alternative lighting design (7) 6-2

Finding an optimal lighting system for 1990s DCS facilities is difficult. These facilities, whether permanent or transportable, are programmed for locations around the world at varying longitudes and latitudes in all kinds of climates. It is likely that any given solution or combination of solutions will neither apply nor be economically justifiable at all programmed locations. These diverse programmed locations dictate the need for more than one optimal lighting system. For this reason, the discussions on available lighting systems will be general.

The lighting systems to be investigated in this study are:

1. Fluorescent
2. Metal halide (MH)
3. High-pressure sodium (HPS)
4. Daylighting, which includes:
 - a. Lighting conduits (fiber optics and light pipes)
 - b. Light shafts
 - c. Periscopes
 - d. Solar connectors (heliostats and compound parabolic concentrators)
 - e. Standard architectural fenestrations (windows, sky-lights clerestories).

Mercury vapor and incandescent electric light sources have been eliminated from consideration because of their relatively low efficacies and low pressure sodium (LPS) has been eliminated because of its monochromatic color rendering properties.

Only the first three lighting sources are total energy consumers. The fourth lighting source, daylight, is an alternative lighting method that can be used in conjunction with one of the electric light sources.

guidance ELECTRICAL/3 Lighting**Electric lighting sources**

Since the energy crisis in 1973, many reductions have been made in consumption of available electric light energy. These sources are well known (fluorescent, MH, and HPS) and have an efficacy in lumens per watt high enough to qualify them for an energy-efficient light source. The trend in the 1990s will be to improve these sources rather than develop new ones. Such research and development to improve available sources may lead to a new, more efficient source, however. It would be conjecture to make assumptions about the nature of new sources; therefore, state-of-the-art systems and their trends will be examined.

In recent years, fluorescent lamps have been redesigned with new phosphors added, resulting in a 15 percent reduction in wattage while retaining nearly the same lumen output. This wattage reduction coupled with the new energy saving ballasts has increased the efficiency of standard 4-foot lamps to 89 lumens per watt. In the 1990's this efficiency will be increased even more with greater use of solid-state, high frequency (3 to 10 kilohertz) ballasts now being developed and tested. Early indications show a 20 percent decrease in energy usage for the same lumen output and these solid-state ballasts can be either switched or dimmed.

MH and HPS, the two more efficient high-intensity discharge (HID) sources, have also been affected by the energy crisis. "Super" versions of the lamps have shown marked increases in lumen output. MH and HPS are now available with efficacies of 90 lumens per watt and 100 lumens per watt, respectively. Even the restrike time inherent with HID sources has been eliminated by some new lamps. These new lamps to date are not as efficient as the standard HID lamps, but by the 1990s may be viable alternatives. Like fluorescent, MH and HPS have and will greatly be influenced by the solid-state high frequency ballasts. Dimming these HID sources, now an expensive proposition with the solid-state ballast, will be very competitive by the 1990s.

The importance of solid-state ballasts for fluorescent and HID sources cannot be stressed enough. By the 1990's, the switching and dimming of electric light sources will be an important element in the total energy package for DCS facilities.

Control of the fluorescent and HID sources will become more sophisticated in the 1990s. Switching will range from the simple on-off function for groups of fixtures by dimming, to the control of individual fixtures with a microprocessor. The microprocessor, already available, will allow for complete control of the lighting systems. This control can be local, remote, both local and remote, time-activated; photocell-activated, or any combination of these modes.

This ability for infinite control will have considerable impact on energy consumption in buildings when coupled with

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daylighting. Savings of 30 to 50 percent in energy consumption may be realized by the judicious use of daylight and dimmable electric light sources controlled by microprocessors and photo controls. Using this combination in DCS facilities for the 1990s would be ideal, but may not be realistic for the hardened, EMP-shielded buildings projected.

Daylighting

The nature of future DCS facilities and their hardened, shielded exteriors, plus the potential of being located underground, make standard fenestrations unrealistic. However, increased interest in solar energy since the 1973 energy crisis has resulted in some innovative designs to bring daylight inside buildings. Several of these methods, including fiber optics, light pipes (large cross section acrylic plastic), light shafts, periscopes, and solar tracking, can be combined to provide a method for introducing daylight inside the 1990s DCS facilities.

The light conduits, which include fiber optics and light pipes with the state-of-the-art design, are hampered by high transmission losses. These materials have the following approximate properties:

Material	Transmission Loss	Conduit Size
Glass fiber optic-normal loss	50%	1"
Glass fiber optic-medium loss	4%	1"
Glass fiber optic-low loss	less than 1%	1"
Plastic fiber optics	80%	1"
Plastic acrylic (light pipes)	70%	any size or shape

***Small fiber strands bundled**

The fiber optics and light pipes may be curved and bent to almost any shape within the restraints of minimum radii for each particular material.

For uses in which excessive heat is involved, plastic conduits must be eliminated, unless the light collectors are cooled in some way. This temperature limitation may not be a problem since the high transmission losses for the plastic light conduits may eliminate them from consideration.

Light conduits require some method by which sunlight can be collected and focused on their ends. The acceptance angles are typically small for low-loss transmission conduits and larger for the higher loss transmission conduits. Methods for collecting sunlight include tracking reflectors (heliostats) and concentrating reflectors (compound parabolic concentrators [CPC]).

These collectors typically must be located above ground and in full view. They must be close to the light conduits and,

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consequently, the DCS facility. This may or may not prove to be a problem, depending on the need for securing each facility from sight.

Another possible method for bringing daylight inside these hardened buildings while still providing some degree of protection against nuclear blasts may be to use a series of mirrors on the principle of the periscope. Thick, high-light transmitting clear plastics coupled with mirrors can provide a large area of light to the facility interior. This method would probably have to include a small cross section ferrous metal grid to maintain EMI integrity. This grid will greatly reduce the system's efficiency.

A final possibility for introducing light inside the facility is by light shafts. These are large cross sectional openings constructed of highly reflectant materials and are used in conjunction with a heliostat or CPC. Use of this method would depend on the location of the facility and on the requirements for hardening or EMF shielding.

In summary, the more energy-efficient lighting systems for the 1990s will be fluorescent, MH, or HPS coupled with one of the daylighting methods. High frequency ballasts, dimming, photo controls, and microprocessors will be available as components of the total system.

f. Visual comfort

Comfort for human eyesight depends on adequate illumination levels, absence of glare, and adequate contrast levels. These three factors can be manipulated within given ranges to attain both energy conservation and comfort.

The first step in reducing energy requirements for the lighting system is the reduction of lighting levels that are too high. It is generally agreed that traditional illumination levels may be higher than needed for comfort or effective task performance.

Another major cause of excessive lighting levels is uniform lighting, especially in offices and stores. Uniform lighting, maintained at a level necessary for the most critical tasks, wastes energy when other, less critical tasks do not require the same amount of illumination. Uniform lighting should be converted to selective or task lighting, when possible.

Brightness contrast is vital in visual communication, but excessive background brightness can disrupt the eye's ability to perceive fine detail. In the extreme, glare or reflections from background brightness can temporarily cripple vision by destroying the observer's ability to adequately perceive a task, obstruction, object, or space. Increasing illumination to increase background brightness is thus not only wasteful, but sometimes defeats the purpose.

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Glare can be corrected by: (1) reducing the source luminance, (2) relocating the source outside the normal visual field, (3) reducing the reflectance of excessively bright surfaces and (4) polarizing light from the source so that the light oscillates in the vertical direction only.

REFLECTION**Degrees of Reflection**

Specular reflection is the reflection that we get from a mirror or other highly polished surface. The following rule applies to specular reflectors: the angle between the reflected light ray and a line perpendicular to the reflecting surface is equal to the angle between the same perpendicular line and the incident light ray. In other words, the angle of incidence equals the angle of reflection.

Reflectors made of specular materials redirect light in precise beam patterns if the source of light is comparatively small. Therefore, very accurate reflected light patterns require that the light source be as small and as compact as possible.

Three reflector shapes are commonly used in lighting equipment. Each can be formed by passing a plane through a conic section. (1) The parabolic shapes are among the most useful. When a point light source is placed at the focus of a parabolic reflector section, all the light rays reflected from the surface are parallel. (2) The elliptical reflector (sometimes called an ellipsoidal reflector) has two focal points. When the point light source is placed at one focus, the rays leaving the reflector converge at the second focus. This second focal point is called the "conjugate focal point." Note that the image of the light source is reversed after it has passed through the conjugate focal point. This characteristic crossing of the rays at a second point in front of the reflector makes it possible to direct a relatively large spread of light through a very small opening. (3) The circular reflector section, the simplest of all the reflector shapes commonly used in lighting. When a point source of light is placed at the center of the circle, the reflected rays pass back directly through the source, increasing the apparent intensity of the source.

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Spread reflection is a second degree of reflection. The spread reflector has numerous small surfaces that lie only on an average plane. For this reason, the majority of light rays striking the spread surface from a point light source follow the direction indicated by the reflector even though in each case the direction is slightly out of line. The result is to maintain the general direction but to "spread" the light a little.

You may note that the surfaces of so-called specular reflectors are frequently roughened to provide a slight degree of diffusion. This process serves to hide beam irregularities caused by filament striations or other light source imperfections.

Diffuse reflection occurs where the reflecting surface redirects incident light in all directions. This obviously eliminates any directionality to the reflected light and tends to offset the effect of a reflector shape. Flat white paint and unfinished white plaster are good examples of diffuse surfaces. Highly diffusing materials appear nearly equal in brightness from all angles of view.

Most materials exhibit characteristics of all three degrees of reflection: specular, spread, and diffuse.

VISUAL RESPONSE TO BRIGHTNESS

The standard used today to determine the acceptability of a lighting installation is a measure of the light falling on an environment (which is expressed in footcandles). However, the eye does not react to incident light; it responds to reflected light (which is expressed in footlamberts). Footcandles are simple calculable quantities indirectly used in developing light levels for seeing. Incident light is modified by the effects of object size, simultaneous contrast, viewing time, and color before we perceive the visual response of light as it is directly involved in the seeing process.

Tolerance variations of the eye to differing levels of reflected or transmitted light are phenomenal. Under controlled circumstances, the eye can perceive minimum variations in brightness of approximately 2 to 1, and variations between the brightest and darkest areas of a seeing task can reach a maximum of 100 to 1. However, extreme contrasts between high and low areas of brightness can strain the eyes and slow the seeing process, particularly if the viewer is subjected to these conditions for long periods of time or engaged in detailed tasks. On the other hand, some contrast is

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essential (both physiologically and psychologically) if seeing is to be comfortable and effective. The problem is to control reflected light for optimum effects.

Brightness can be divided into two categories. Subjective brightness is the conscious light sensation resulting in the feeling of intensity. Here we have a vast range of words to describe the effect including: dark and light, dim and bright, etc. Photometric brightness refers to a measured amount of brightness. Photometric brightness is also called luminance.

UNWANTED BRIGHTNESS VARIATIONS**Glare**

Unwanted brightness variations are described as glare. The Illuminating Engineering Society defines glare as "the sensation produced by luminance (sic) within the visual field that are sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance and visibility."

GLARE

There are two types of glare: direct and indirect. Direct glare is described as light shining directly in the eyes. The situation is so annoying, it is usually fixed as soon as it occurs. People complain so vociferously about the offending light that it is disconnected. Indirect glare encompasses light that shines first on one surface and then reflects from that surface into the eyes. An example is the task light which shines too brightly on a piece of paper. The words written on the paper can be read only with difficulty. They appear washed out - or as if one were reading through a veil drawn across the eyes. That is why indirect glare is often called the veiling reflection.

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Indirect glare can be alleviated by moving the paper, body position, or task light. This is the reason movable task lights have become very popular lately. Unfortunately, people can be bothered by indirect glare without being conscious of it. Those working at video display terminals may suffer headaches, nausea, and even burning eyes from reflections on the screen. Rather than spend large sums of money, the managers may simply have the lighting levels lowered, but too dim illuminations encourages drowsiness.

Daylight also creates glare. Although most people welcome a glimpse of daylight into the working environment and its proper use can save artificial lighting requirements, uncontrolled daylight is glaring and, particularly in the summer months, hot and uncomfortable. The heat produced can be enormous. After all, visible light and heat are part of the same electromagnetic spectrum.

Daylight tends to be very bright light. The strongest interior lighting cannot match its intensity on a sunny day. As a matter of fact, lighted signs must be brighter during the day than at night to bring attention to themselves. The same is true of video display terminals. Depending upon the orientation of the windows, the angle of the sun, and the interior surfaces upon which it reflects, strong daylight can make seeing difficult. Then, too, daylight is rarely constant. It changes as the sun and clouds move across the sky. Where bright days may create too much glare, rainy days create dark, depressing effects. It is imperative then to filter daylight to provide more even light.

There are a variety of methods used to filter daylight. Many office buildings are constructed with tinted windows. Where existing windows are untinted, transparent, one-way sun-reflective materials are available that adhere directly to the glass. The materials reflect a portion of the incoming light and heat. Semitransparent sun screens work in similar fashion. Vertical blinds, venetian blinds, draperies, and shades are also used to control daylight. Here, it is necessary to avoid strong colors since light passing through the window treatment or reflecting from it can modify interior light.

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g. Lighting design

Quality determination methods relate to measurement of the glare present in a lighting system. Glare can be loosely divided into two types: direct and indirect. Direct glares are associated with tasks in a head-up position, and indirect glares are associated with tasks in head-down position. Direct glare results mainly from two types of sources. The first is an excessively bright luminous source shining into a person's eyes so as to reduce his or her ability to see the task. This is also known as a "disability glare." Looking straight at the high beam of an oncoming car is an example of disability glare. The other type of direct glare is due to peripheral stray light that is not necessarily aimed specifically at the eye. This is known as "discomfort glare." Indirect glare is the result of the mirror effect of the tasks that reflect the light source from tasks to the viewer's eyes, resulting in a visibility loss. Direct glare is measured in terms of Visual Comfort Probability (VCP) and, in essence, measures the "discomfort factor of direct glare." Indirect glare is measured in terms of Equivalent Sphere Illumination (ESI). (189) 127

In an effort to provide good-quality design, it is necessary that VCP and ESI values of a lighting system be as high as possible. This presents a problem since their operation principles oppose each other. The direct glare zone is between 45 and 90 degrees. For a high value of VCP, it is necessary that the luminescence associated with this zone be as low as possible and that the light emerge through the 0 to 45 degree zone. The indirect glare zone, on the other hand, is between 45 and 90 degrees. A lighting design will thus evaluate the importance of each and create a design that will be most suitable for the purpose. (189) 127

VCP values can be obtained either by hand calculations or by computer programming. Hand calculations are tedious and time-consuming. If a request is made, manufacturers usually will supply a table of the VCP values of their luminaires along with the photometric report.

Limitations of VCP--Several limitations prevent the determined VCP value from being totally accurate. Although standard conditions are selected to match most indoor lighting conditions, these are effective only for making a preliminary evaluation. The layout, luminaire mounting height, illuminance level, and room dimensions used in the design may never match standard conditions; hence, the "nearest" value received from the VCP table may be far from precise. The VCP evaluation method applies only to spaces with uniformly distributed luminaires; its values are not suitable for nonuniform layout or for uniformly distributed indirect lighting. (189) 130

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Effect of VCP on energy consideration--Although VCP is a technique for measuring the direct-glare aspects of quality design, its impact on energy conservation also can be significant. The technique works on the assumption of uniformly distributed luminaires; such a layout usually represents more energy consumption than nonuniform task lighting. The other factor is that luminaires with high VCP usually have low efficiency. Highly efficient luminaires offer more light per watt, with a substantial amount of light emerged through the direct-glare zones. This causes opposition to achieving high VCP values. The usual way to increase the VCP of such luminaires is with special nonglaring louvers or modified lenses that form physical barriers to light emerging from the direct glare zone; this reduces efficiency substantially. (189) 131

Dimming may be considered as a solution to this problem. Continuous dimming of these luminaires will gradually decrease the glare all around and increase VCP with insignificant change in the luminaire's efficiency. For fluorescents and mercury vapor, the percentage of light output is almost directly proportional to the input power. (189) 131

VCP ratings should be compared only if applicable areas and situations are identical and if luminaires under consideration are the only variables. It should be remembered that standard VCP data are calculated with a preset group of parameters, including the observer's looking straight ahead and sitting at the center of the rear of the room. These conditions apply more to offices or schools, rather than industrial interiors. Visual comfort is one of the desirable factors in lighting systems and should be kept in proper perspective in relation to other objectives, such as energy conservation, cost, and productivity. (189) 132

Indirect glare and the veiling reflection--Indirect or reflected glare mainly results from light emitted in the 0 to 45 degree zone, reflecting off a shiny or glossy surface and pointed toward the eyes. The patches of light visible on the surface are the light source images. The glossier or more specular the surface of reflection, the more distinct the image of the source, causing a loss in visibility. Depending on the angle and direction of the light rays, the reflected glare can be distracting and annoying and the main reason for visibility loss. (189) 132

A ray of light arriving from an angle and direction such that it hinders visibility is termed a "poor ray." In contrast, another ray arriving at an angle and direction that improves visibility is a "good ray." Depending on various angles and directions of arrival on the task, the rays can be graded in different types of rays (see the figure). The

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Figure shows the grading of light rays with respect to direction of arrival, and the subsequent figure shows grading with respect to angles of arrival. The angle and direction at which the viewer sees the task are known as the "viewing angle" and "viewing direction." Note that as the rays of light striking the task move away from the front of the viewer towards the back, visibility improves. The worst visibility occurs at an angle and direction of light rays that reflect off the task and head directly to the viewer's eyes. The combination of all such poor and bad rays hinders visibility by creating a "veil" on the task, known as the "veiling reflection." (189) 133

Veiling reflection reduces the contrast of the task, reducing visibility and visual performance. This basically means that room lighting may actually hinder visibility rather than improve it, if light rays are striking the task from bad angles and directions. The complete lighting system, including types of luminaires, their locations, and room-surface reflectances, among others, will interact with the task microstructure, reducing contrast and hence adversely affecting visibility. This effect of loss in contrast or veiling reflection is measured in terms of ESI. The root of the ESI technique is based on the Blackwell Contrast Formula: (189) 133

$$C = \frac{L_o - L_b}{L_b}$$

where

C = Contrast
 L_o = Luminance of the object
 L_b = Luminance of the background.

Various factors affect contrast:

- Room dimension
- Room-surface reflectances
- Luminaire layout
- Candle power distribution of luminaire and polarization
- Viewing angle
- Viewing direction
- Physical characteristics of the task
- Test location.

In relating the concept of ESI to real environments, the following hypothetical example can be used. The second figure shows a real, everyday lighting environment in which light rays, either directly from luminaires or bouncing from room

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surfaces, strike the task at various angles and directions. Under these conditions, typical tasks, such as a book or a letter with black print on white pages, may not be satisfactorily visible, although a light meter near the task may read as high as 100 footcandles. The task is now placed inside a photometric sphere that provides the same visibility of the same task at the same viewing angle as was encountered in the room. A light meter reading the illuminance level inside the sphere now may read a considerably smaller footcandle value--say, 50 footcandles (see the figure below). The ESI of the task in the room now can be claimed to have 50 ESI footcandles since this is the equivalent of 100 footcandles in the room. (189) 134

Note that an improvement in maximum or average ESI does not necessarily mean an improvement in minimum value. Compare the values for the pencil and drafting tasks.

Determination of task contrast is the main problem since its value depends on so many factors, as discussed earlier. This is the main reason a computer must be used instead of hand calculations. If all the hard-to-find parameters are available, the remaining mathematics are quite easy in determining the ESI value. Several programs are commercially available through time-sharing terminals. The following are the major steps involved in determining ESI. (189) 139

Step 1: Determination of L_b , L_o , P_o , E_t , and C_o . All of these can be measured directly if ESI has to be determined in reality, i.e., in an existing situation. Since most applications are in a design stage, they must be calculated. Determination of L_b (luminescence of the background of the task, e.g., the white page) and L_o (luminescence of the object on the task, e.g., the back printing on the paper) depends on E_t (illuminance on task at the location), which must be calculated. This is possibly the most complicated part of the whole procedure, since illuminance at a point E_t in the room is attributable to (1) direct light from luminaires and (2) interreflected light from room surfaces. Although illuminance attributed from luminaires can be calculated directly, the room surfaces must be considered as a cluster of several small sources to be qualified for using the point-by-point method. For this, the luminance of surfaces must be determined first, and then they must be broken into several small areas to simulate the clustered light sources. Most of the information required in determining the ESI values is used at this stage, and a computer must be used for the complex calculations involved. P_o (diffuse reflectance of the task background in sphere) and C_o (contrast of task in sphere) are predetermined figures and are constants for a specific type of task.

A sphere is used as the reference mainly because it is easily reproducible and because experiments have shown that proper placement of the task within an evenly illuminated

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spherical surface produces good task contrast. However, the important point to remember is that a photometric sphere does not necessarily represent the ideal or best lighting system; it is merely used as a reference. In addition, the ESI footcandle value determined for an application is valid only for the specific type of task, viewed at a specific angle and direction, with specific luminaires and orientation, and with given room-surface reflectances. A change in viewing direction or angle or a change of the type of task (which often happens) will alter the ESI greatly. For these reasons, an average ESI value determined from various ESI values at different parts of the room will be meaningless. (189) 135

Determination of an ESI value for an application is a complex process since there are so many contributing factors to be accounted for. Most calculations are based on a 25 degree viewing angle since this appears to be the most common angle of viewing by an average person. The type of task may also vary greatly. The most common task used in ESI determination is a "pencil task": representing concentric rings drawn in pencil on white bond paper. Several commercial computer programs are available for ESI determination. Each program usually can calculate values for different types of common tasks. For instance, one popular program offers the following types of tasks: (189) 135

- Pencil on white bond paper
- Typewriting on white bond paper
- Ballpoint pen on blue-lined tablet paper
- Pencil on mylar drafting film
- Offset printing on glossy paper
- Dry copier on matte white paper
- Felt-tip pen on matte white paper

It is important to remember that the ESI of a point may vary greatly among tasks even if other variables are unchanged. This is because the contrast of the "print" relative to its background and the specular characteristics of the print and background together may be substantially different for one type of task compared to another. To show the variance in ESI values resulting from changes in task types, the following table was developed using a popular program, with all other variables unchanged. (189) 138

Task	Avg. of all points	Max. value	Min. value
Pencil	49	96	5
Typewritten	90	122	13
Ballpoint	82	120	11
Drafting	66	162	3
Offset	96	197	4
Dry copier	85	135	9
Felt tip	89	125	12

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Step 2: C (contrast of task in real environment) is calculated by the Blackwell Contrast Formula since L_o and L_b are known from Step 1.

Step 3: CRF (the contrast rendition factor) is determined by dividing C by C_o .

Step 4: RCS (the relative contrast sensitivity) in the real environment is determined from the table or curve corresponding to the L_b found in Step 1. The curves can be found in the IES handbook.

Step 5: RCS_e (the relative contrast sensitivity) in the sphere is determined by multiplying RCS and CRF. This step in essence takes into account the veiling reflections.

Step 6: Using the same table or curve of Step 4, L_e (the equivalent background luminescence of the task in sphere) is found corresponding to RCS_e .

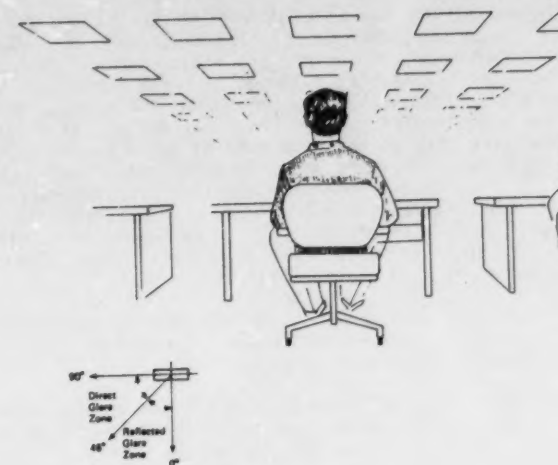
Step 7: ESI value is determined by dividing L_e by P_o , the predetermined constant value for the diffuse reflectance of the task background in sphere.

A lighting effectiveness factor (LEF) is the ratio of ESI to E_t and represents a percentage of the illuminance found in a real environment, which can produce the same glare-free visibility as can be found in the reference sphere. (189) 140

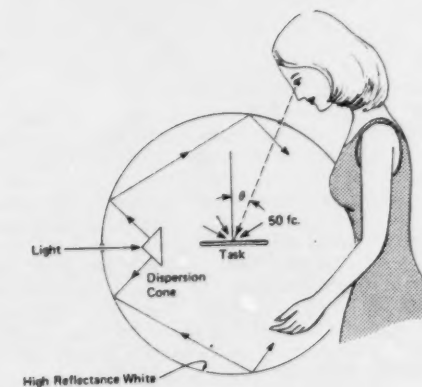
As mentioned earlier, several programs are commercially available for determining ESI and VCP. Many luminaire manufacturers offer free service of such programs for calculations related to their own products. Whatever route is taken, all programs require the initial information in design criteria and parameters, which can be presented in a format of input data. (189) 140

Although ESI values are important for good lighting judgment, they should be used only when quality of visibility is important. For other noncritical areas, ESI is practically useless. ESI is a good tool for analyzing a lighting system or for comparing different luminaires for the same visibility; however, it should not be used as the only criterion for the final decision. It is one of many criteria to be considered in lighting design. (189) 147

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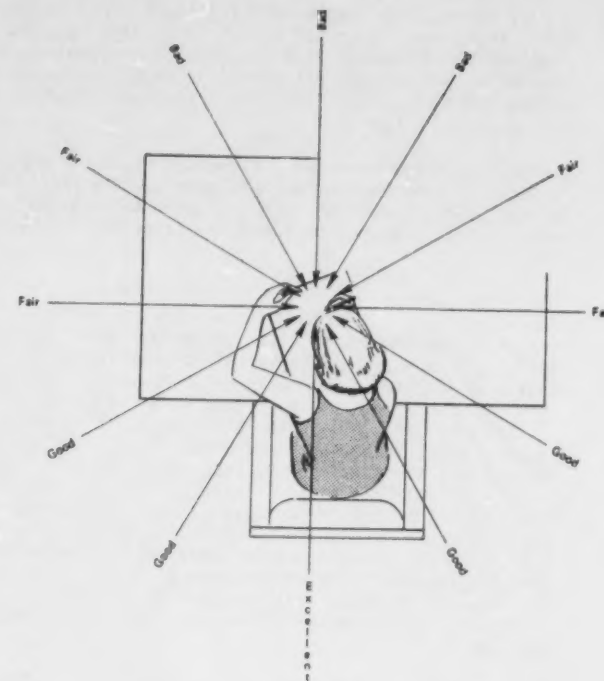


HIGH AMOUNT OF LIGHT AT DIRECT-GLARE ZONE CAUSES DISCOMFORT GLARE.
HIGH AMOUNT OF LIGHT AT INDIRECT-GLARE ZONE CAUSES A LOSS IN VISIBILITY. (189) 128



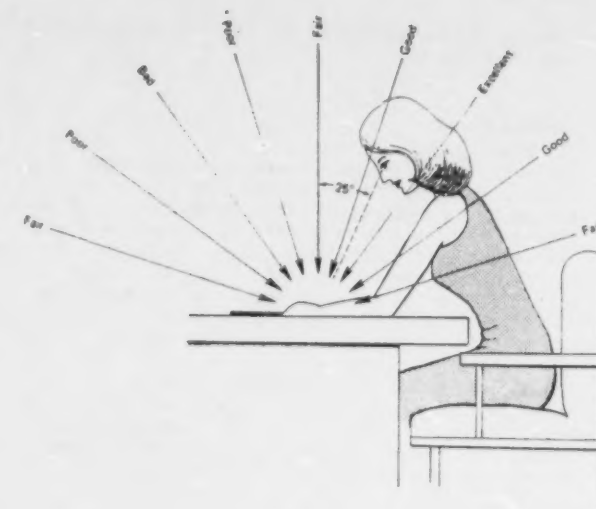
A LIGHT METER READING THE ILLUMINATION LEVEL INSIDE THE SPHERE MAY READ A CONSIDERABLY SMALLER FOOTCANDLE LEVEL, SAY, 50 FC. (189) 138

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(A) GRADING OF LIGHT RAYS WITH RESPECT TO DIRECTION OF ARRIVAL. (189) 134

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(B) GRADING OF LIGHT RAYS WITH RESPECT TO ANGLE OF ARRIVAL. (189) 135

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h. LIGHTING SYSTEM CONTROL:

The control of electricity is one of the most exciting subjects in the study of lighting, but it is also one of the least understood and poorest applied of the lighting tools. Very few designers realize how much can be accomplished with innovative control.

DIMMING

Dimming is the variation of lighting intensity over a continuous range.

Dimming Curve

The way that light output responds to changes in the control setting is called the dimming curve. If a change in the setting of the dimming control, from full bright to full dim, approximately equals a change in the amount of electricity allowed to reach the light source, the dimmer is said to have a linear curve. However, the eye is more sensitive to changes in low light levels than changes at high levels. Even if the electrical output of a dimmer changes in a linear manner, a light source will appear to dim faster at low levels and slower at high light levels. To correct this, dimmers may feature a "square law" dimming curve. Here the dimmer control moves at a constant speed, but causes the light to dim faster at high levels and slower at low levels. To the eye, the effect is a constant dimming speed. Both logarithmic and linear dimming curves are supplied by equipment manufacturers.

Incandescent Dimmers

Dimming methods are first governed by the way in which sources produce light. Separate systems exist for incandescent, fluorescent, and HID technologies. Incandescent dimming has the longest history.

Resistance Dimming

The first dimming system used for incandescent sources was the resistance type. It consisted of a long wire that was attached to the power supply and was formed of metals that resisted the flow of electrons over its entire length. Connected to the incandescent source was a second wire attached to a "shoe" or "wiper" that slid along the resistance wire.

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The resistance wire had to be very long so that it could absorb all the energy that was required. For this reason, it was often coiled on itself. Because the shoe actually moved over an exposed section of this coil, the dimming was actually completed in a series of steps (often a minimum of 110 for flickerless control). The shoe was connected to an insulated mechanism, called "dead front," that prevented the operator from touching any of the electrically "live" parts as he moved the shoe. (All electrical controls should be of the dead-front type.)

In many of the resistance dimmers used for lighting practice, the resistance coils were wound more closely at the bright end of the dimming curve than at the dim end. This feature produced a logarithmic dimming curve.

The chief advantages of the resistance dimmer are its low cost and electrical simplicity. However, the following disadvantages far outweigh this system's usefulness in contemporary architectural lighting: (1) Resistance dimmers are heavy and bulky. (2) They are only effective within a very restricted capacity range. For example, if a dimmer is rated for 50 to 60 watts, a 25-watt lamp will not dim evenly. (3) Resistance dimmers are sensitive to the load they carry. If three lamps are attached to a resistance circuit, they will dim when a fourth is added, even though the control has not been moved. (4) The electrical power that is not used by a lamp in the dimmed position is discarded by the resistance dimmer in the form of heat; the lower the dimmer reading, the hotter the dimmer. This feature wastes electrical energy and creates cooling problems.

Autotransformer Dimming

An advance in incandescent dimming was achieved with the development of variable transformers. A simple transformer consists of two separate coils of wire mounted in such a way that the coils have overlapping magnetic fields. Therefore, the magnetic field created in the "primary" coil by the alternating current passing through it induces another magnetic field to pass through a "secondary" coil. The alternating voltage in the first coil induces voltage in the second coil. By varying the number of turns in the second coil, the amount of voltage it produces can be decreased or increased. If electric power is drawn from different points on the secondary coil, we can (in basic theory) achieve different voltages from the same transformer.

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The action of the basic autotransformer is roughly similar to selecting different voltage outputs from a simple transformer, although certain modifications in the circuitry make the continuously variable autotransformer operate effectively.

The autotransformer has the following advantages over the resistance dimmer: (1) It will evenly dim a wide range of wattages, from a few watts to its full electrical rating. (2) It will operate all wattages connected to it through the same dimming range. High-wattage lamps will dim over the same curve as low-wattage lamps. (3) Lamps can be added to or subtracted from an autotransformer controlled circuit without affecting the other lamps already on the circuit. (4) The dimmer is cool in operation since unused power is not dissipated as heat. Most electrical power not used by the lamp is simply not used.

There are, however, three disadvantages: (1) Although frequently smaller than the resistance dimmer, the autotransformer still requires considerable space. As an example, a dimmer used to control only 200 watts requires a wall area measuring 5 by 5 wide by 3 inches. If the wall-mounted autotransformer must control 800 watts, it may require approximately 10 by 7 1/2 by 3 3/4 inches. (2) The autotransformer is comparatively expensive. (3) The autotransformer is heavy when compared to new dimming systems.

Solid-state Dimming

Most solid-state dimming systems are based on the use of a "thyristor." This term encompasses power control devices such as triacs, silicon controlled rectifiers (SCR), and silicon controlled switches (SCS). These solid-state devices allow electric current to flow at full voltage, but only for a portion of the time. This causes the incandescent lamp to dim as if the voltage were reduced (as with the autotransformer). The timing of the solid-state device is controlled by a low-voltage source that can be remotely varied. A small variable current, therefore, causes a larger one to change.

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With one of the most common thyristors, the SCR, two types of circuit can be considered. If there is only one SCR in the dimming circuit, dimming is accomplished by partially or completely eliminating half of an alternating current's cycle. Two SCRs mounted back to back, permit a controlled amount of current to pass during each half cycle of the full AC voltage cycle. With SCRs, control is obtained by what is called "gating action;" a very small and variable DC voltage is applied to the gate (controlling element) of the SCR. This voltage activates the SCR and times the voltage that is allowed to flow.

Solid-state dimming systems have the following advantages: (1) They are very small. A 600-watt dimmer, for example, can fit into a standard wall switch enclosure (about 2 1/2 by 3 1/2 by 2 inches). (2) Thyristor dimmers are efficient, since there is little power loss caused by the dimmer itself. (3) They are insensitive to changes in incandescent load up to their rated capacity. (4) They are relatively cool in operation. (5) They adapt easily to miniaturization and programmed remote control. (6) The dimmers are inert and require no maintenance. (7) They are comparatively inexpensive, particularly when used to control lower wattages (to 1000 watts).

As with all control devices, thyristors have certain disadvantages. (1) They are fragile. Thyristors will take neither the electrical nor physical abuse that can be absorbed by an autotransformer (when they fail, they stay at full on). (2) They may cause noise in associated systems. Thyristors can cause lamps to "sing" (a high buzz) and/or create interference with electronic audio or television equipment.

Other Systems

Other types of incandescent dimming systems have been used in the past, but are rarely installed today. These systems, which may be encountered in older installations are: magnetic amplifiers, reactors, and electronic tubes (thyatron tubes).

Fluorescent Dimmers

Fluorescent light sources can be successfully dimmed through the control of electric power. Two systems are commonly used: the autotransformer and the solid-state dimmer.

The autotransformer was the first system employed for fluorescent service. Presently, it is used primarily for small installations.

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The autotransformer has been largely displaced by the solid-state dimmer. In a simple installation, the solid-state dimming system is comparatively uncomplicated. When large numbers of fluorescent lamps are dimmed, however, the system must be more sophisticated. Advanced systems should be developed by a lighting expert (lighting consultant, engineer, or manufacturer). All components of the system should be supplied by one manufacturer so that they will be coordinated.

Environmental designers should be aware of the following details concerning application of solid-state systems: (1) Only rapid start fluorescent lamps can be used. During the dimming cycle, the electrodes of these lamps must remain heated. Instant start and preheat lamp electrodes are turned off after the lamps are started. (2) A dimming ballast must be used, and this ballast must be compatible with the dimmer or this ballast must be installed. Dimmer and ballast dimming system will help in the selection of appropriate manufacturers will help in the selection of appropriate components. (3) Fluorescent lamps will not dim all the way off. If they are allowed to dim too far, the lamps will flicker or a luminous spiraling form will be seen within the bulb. Most fluorescent dimmers have an adjustment that prevents the user from dimming the lamp beyond a maximum down position. On the small and simpler systems, this control is usually found under the face plate and is located near the main adjustment knob. Once the maximum down position has been reached, the lamps must be turned off with a switch. When a fluorescent dimming system is planned, it should be kept in mind that the lamps will still be faintly illuminated when dimmed to their maximum. (4) The use of a starting aid is essential. The starting aid should be in the form of a 1-inch wide metal strip placed within approximately 1 inch of the lamp bulb, and it must extend along the entire length of the bulb. A fluorescent housing will often serve as a starting aid. In all cases, the ballast case must be electrically connected to the starting aid. (5) Only 3- and 4-foot lamps can be dimmed by most systems. All lamps controlled by a single system should be of the same length or they will not dim at the same rate. (6) Fluorescent lamps used in dimming systems should be new, and it is wise practice to install them all at the same time. As some of the lamps grow old and begin to flicker, the complete set of lamps can be moved to a nondimming part of an installation and replaced with a fresh supply.

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High Intensity Discharge Dimmers

Until recently, it was not possible to dim HID sources by controlling their electric power. When dimming was absolutely necessary, mechanical methods were used. These mechanical systems consisted of filters, shutters, or louvers that moved in front of the source to selectively block its light output.

Solid-state HID dimming systems have recently been introduced. As of this writing, their application and effectiveness are poorly understood. HID dimming is currently limited to certain mercury vapor (clear or color-corrected) lamps.

TIMING AND PROGRAMMING

Simplified "on" and "off" timing of electrical circuits is common at present; multiple selection of complex illumination programs is rarely applied in architecture. However, in programmed lighting, switching and dimming of many circuits can be accomplished on command, according to time, or based on other environmental conditions such as light and sound levels, moisture, and traffic flow.

1. ILLUMINATION REQUIREMENTS FOR VISUAL DISPLAY TERMINALS

The information contained in this section was retrieved from a nationwide network of library vendors that maintain a bibliographic database containing articles and journals synonymous with their particular specialty. Using existing telecommunication lines via a modem, it was possible to telephone each network and instruct a terminal to search the database for combinations of keywords that may be used in titles of articles containing pertinent information. Articles that contain a combination of these keywords were displayed and off-line bibliographic reports were produced. Pertinent articles or journals (back to 1981) were then retrieved from the University of Illinois (Urbana-Champaign campus) Library. This information was supplemented with reports published by a leading United States Visual Display Terminal (VDT) manufacturer, as well as those given at an Illuminating Engineering Society of North America (IESNA) Regional Conference.

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On the following pages are the results of these investigations and what is believed to be the state-of-the-art with respect to office illumination, lighting techniques in spaces with VDTs, and their impact on the office worker.

The State-of-the-Art Illumination Requirements for Visual Display Terminals

Since the introduction of the desk top computer into the office environment, a whole new realm of problems have arisen, the Ergonomists, lighting designers, office equipment manufacturers, and Visual Display Terminal (VDT) manufacturers have seized the opportunity to study and evaluate the various problems that have become apparent to those workers being required to use this "new" equipment. Problems under current investigation involve worker posture; hand and arm placement in relation to blood circulation and muscle fatigue; impact of the computer-equipment "footprint" on the desktop; and visual task differences and deficiencies caused by a gamut of factors, which are of primary concern in this report.

It is being recognized that although a human being can adapt to various and different conditions in the environment while remaining a productive employee, it should be understood that the human being is also a biological machine that, like other mechanisms, contains the potential to reach a state of optimum efficiency. This, with this idea in mind, and the fact that labor costs are usually the most expensive item on the annual budget, it is wise management to provide conditions that enable employees to achieve their optimum efficiency. In terms of lighting, experience has indicated that the benefits derived from a wise investment in lighting take many forms: increased productivity, better workmanship, higher accuracy, improved performance by older workers, greater eye comfort, less stress, fewer accidents, higher worker morale and job satisfaction, and improved cleanliness in the space. Office workers that responded to a national polling organization question, "What makes a comfortable office?" answered "good lighting" 85 per cent of the time, and "a comfortable chair" answered 73 percent. Since lighting is so important to employee performance, a review of the latest information, concerning visual task differences and deficiencies, shall be discussed in the following order: 1) the relation of the human visual system to the illumination needed to perform a task; 2) the impact the human

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visual system/illumination system relationship has on performance; 3) problems arising from improper lighting design (particularly when viewing a VDT screen); and 4) a discussion of the most recent recommendations as a solution to the problems presented.

The human visual system with respect to incident light waves is composed of two subsystems. The first is the light refractive mechanisms contained in the eye; the second is the receptor system. Each subsystem responds to incident light in its own unique manner, and is age-dependent in that its functional abilities diminish with age.

The refractive subsystem is composed of the cornea, the aqueous humour (the small liquid filled cavity between the cornea and the lens), and the lens. Each of the above components refract incident light to enable it to focus on the retina. It has been discovered, however, that each of these components, particularly the lens, refracts the different wavelengths, that make up white light, at different angles much in the same way that a prism refracts white light into the colors of the spectrum. Research, using young observers, has found that incident wavelengths of light within the range of red are refracted such that they come to focus behind the retina when observer is focusing on a task at a distance of approximately one meter; consequently, wavelengths of light in the yellow range do focus on the retina at that distance and wavelengths of light in the blue range focus in front of the retina. Because the refractive media bends the wavelengths of light as it does, when a point object is illuminated by white light a relatively blurred retinal image results. Therefore it seems that by reducing the wavelengths of light to a relatively narrow bandwidth, such as high pressure sodium light, visual acuity would be improved for tasks at one meter. However, with monochromatic light, the range of refractive power limits the range of viewing distance. Additionally, it has been shown that people cannot accommodate (bringing objects at different distances to focus) properly working in monochromatic light. Thus it would seem that in work conditions requiring great amounts of reading and writing, white light, with generous amounts of wavelengths in the blue range, would be appropriate, while for tasks such as reading a VDT screen, which usually occur at distances close to a meter, it would seem that yellow light or even yellow characters on a VDT screen might be most appropriate.

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As stated above, the research conducted involved young observers. However, as a worker ages, certain changes occur in the refractive subsystem that cause additional phenomenon to occur which result in decreased seeing ability. As a person ages, the lens becomes thicker and less clear as a body itself. This results in light scatter. Additional scatter is produced from diffuse transmission through the sclera and iris (both of which block out light in early years). Flares and specular reflections also occur at various refractive surfaces. The results of these phenomenon occurring can account for up to a 50 per cent reduction in light reaching the retina by age 50, and by age 60, a 66 per cent reduction versus age 20. This correlates well with other research that indicates that older workers require more light than younger workers to perform the same task at relatively the same performance levels. Other implications, of light scatter within the eyes, are reduced visibility (the ability to see detail) through contrast reduction and brightness problems in spaces lacking proper brightness control.

The second visual subsystem is the receptor subsystem that involves the process of receiving wavelengths of light, reacting to those wavelengths, and sending signals along the optic nerve to the visual cortex of the brain where visual images and colors are actually produced. The retina contains receptors called rods and cones. Physiologists have determined that rods, although not color sensitive, are contrast sensitive. The cones, however, are more complicated. There are three types of cone groups that are each sensitive to wavelengths in the red, green, and blue ranges respectively. The various amounts of stimuli produced on each cone group, in conjunction with the rods, by incident light are combined, programmed, and relayed to the brain to produce the visual image.

As stated earlier, it is believed that the human body has states of peak efficiency; this is also true for each of the three cone groups. The red, green, and blue cones each have a peak spectral response at 610 nm, 540 nm, and 450 nm respectively. Visual preference experiments have indicated that color memory in people tends to shift towards these peak responses and people have a preference for colors with a spectral reflectivity strong in these three peaks.

Electric lamps have been developed with spectral distribution strong in these peaks, and human responses to tests using these lamps have indicated that color preference and visual clarity is improved. Concurrent tests were also performed using high pressure sodium lamplight that happens to have a spectral power

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distribution peak between the points of maximum cone response. It was found that not only is the color rendering performance worse, but that visual clarity of tasks such as reading and writing were impaired. In another test conducted using High Pressure Sodium (HPS) and Cool White fluorescent (CW) lamp light, respondents indicated that reading under HPS was more hazy, calculated by a factor of 4 per cent, thus causing relatively more "trouble with focus" than CW lamp light.

The impact of the relationship between the visual system and illumination indicates that performance is affected when the characteristics of a lighted environment are in conflict with the visual system. What this can mean for employees includes difficulty seeing, headaches, and decreased efficiency. For employers it means lower worker moral, lower productivity, and higher costs.

A conclusion can thus be drawn that a work environment should be illuminated with non-monochromatic light, preferably white light in the range of peak cone response designed and installed in such a way that brightness is controlled, task contrast improved, and ceiling reflections and glare are minimized. When installing a desk top computer (with a VDT) in the office environment, there are additional problems that may arise when attempting to view the VDT screen. There are four types of VDT screens in use today: Light Emitting Diodes (LED), Liquid Crystal Display (LCD), plasma panels, and the Cathode Ray Tube (CRT), which is the most common. Although questions and concerns have arisen about radiation emission, and eye fatigue brought about by screen image flicker, studies are also on-going with respect to ergonomic relations of the operator to the screen. These are not problems associated with the lighting design of the office environment and do not fall within the scope of this study. However, problems have arisen with respect to lighting design that shall be addressed. The most prevalent problem associated with the lighting is glare, or images of the light fixtures located in the ceilings or on desks appearing in the screen. The other is eye fatigue from contrast differences when shifting from the source document (typically typed paper) to the CRT screen.

Solutions to the image in the screen problem are available. Although it is unfortunate that the VDT manufacturers refuse to develop glare free display screens that would eliminate the problem at the source, alternative means have been developed. The first alternative is to install a nylon mesh screen in front of the VDT screen. There are manufacturers that make

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these screens to fit virtually any brand of VDT terminal now produced. These screens do eliminate glare and reflections from the screen. They also improve contrast because the mesh is dark charcoal in color and they allow flexibility of screen location within a space. However, they also enhance the perception of flicker. It should be determined by the potential user, therefore, whether the pros outweigh the cons to this solution. The solutions deal with the source of the glare, and the following steps have been prescribed by others:

1. Where recessed luminaires such as 2' x 2' or 2' x 4' fluorescent or HPS are in use, replace the existing lens with a specular parabolic wedge louver. This will redistribute the light geometry to have a cutoff of 45 degrees. There are, however, wedge louvers available up to 6" of depth. No mention of recommended depth was made which has an impact on the amount of specular reflections visible to the observer and on light fixture depth in retrofit situations. Above the parabolic louver, install a translucent white diffuser panel. This will eliminate specular reflections of lamp images if the louver and prohibit raw light to come between the louver grid as well as prohibit viewing an unsightly bare lamp in the fixture when looking at the ceiling.
2. If windows are present, install vertical blinds that can be adjusted to direct incoming light away from the screens or sheer drapes. This permits adjustment of luminance at the windows but eliminates the screen operator from viewing the out-of-doors unless he gets up away from the workstation. To permit viewing out-of-doors, as well as reducing the amount of light coming through the windows, install the mesh-type window whading device that is now available.
3. Position the VDT terminals away from any windows, or if possible locate VDT's in a separate windowless room. Additionally, do not position any two screens back to back.
4. If possible, replace ceiling down lights with indirect lighting fixtures that direct light laterally.
5. Instruct employees to not wear white blouses or shirts, as these also cause reflections or issue dark bib aprons that can be worn while in front of the screen.

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6. Control luminances within the space by refinishing walls and surfaces to have a diffuse, matte finish with reflectance values of 50 per cent or lower. The net reported results are these: a) you generally obtain even shadow-free illumination at the work level and, b) the light source is eliminated as a glare source.

To eliminate extreme contrast in the immediate task surround (which is a 5 degree cone around the task), a recommended luminance ratio of 3:1 between task and darker surrounds should be maintained. This includes the space between the source document and the VDT screen. This keeps the transient adaptation factor to a reduction of only 10 per cent of effective contrast whenever fixation changes from one source document to another. The luminance of a source document and the character on a VDT screen should be adjusted to be equal. If these recommendations are carried out, eye fatigue from too many changes in contrast should be reduced.

By following the recommendations set forth for VDT screens, the ambient level of light will be reduced. However, it is known that older workers need more light to perform their tasks, but more light causes increased light scatter within their eyes. The visual process actually works by perceiving differences in contrast, and small improvements in contrast can cause significant improvements in visibility. Since scatter is caused by brightness and recommendations have been made to control it, tests should be taken before raising ambient light levels. Thus, for older workers, a small task light may be all that is required to illuminate the task surround in order to achieve good visibility.

Good lighting design for offices with VDT's is possible and the information contained herein is the latest available. However, many of these recommendations are based on laboratory research with each research project looking for results of one particular parameter. There are some new installations being constructed utilizing these ideas around the country, but retrofitting an existing installation poses more parameters. It would be interesting and useful to retrofit and existing space following all the recommendations above and conduct additional research in the following manner. After sufficient time has elapsed, and not allowing workers into the existing area to make comparisons, have them grade the new environment on a 7-point differential scale, whether they like the lighting, visibility of task, etc., while additional measurements are taken to see whether productivity increases to justify the expense of a total retrofit.

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DCA CIRCULAR 300-95-1

3-1

SB3
Fire Protection / Life Safety

References

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Fire Protection/Life Safety SB3

function

Each DCS facility must be designed to provide a reasonable degree of fire protection and life safety from fire, smoke, fumes, or panic. Fire protection includes recommendations for building materials and methods of construction, as well as the design of detection, notification, and suppression systems. Life safety includes the design for an adequate means of egress from the facility or into safe areas of refuge within the facility, as well as safe illumination and smoke removal.

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1. The requirements in this chapter are based on the National Fire Protection Association (NFPA) National Fire Codes (NFC), International Conference of Building Officials Uniform Building Code (UBC), and Occupational Safety and Health Administration (OSHA) Standards, and are not intended to conflict with DOD Construction Criteria Manual DOD-4270.1-M. When a conflict exists, the most stringent rule shall apply. (136) 13-1
2. Special problems not covered by DOD criteria, NFPA standards, or this chapter shall be referred to the proper military department for guidance. Deviation from these criteria, when a valid need exists and when an alternative solution involving sound fire protection engineering is available, may be accepted after approval by the proper military department. Requests for approval must include justification, cost comparison, criteria used, and other pertinent data. (136) 13-1
3. Deviations or waivers from established criteria require prior approval by the military department. The "authority having jurisdiction" in referenced codes and standards are the following:

Air Force: HQ USAF/LEEE
 Army: HQ USACE/DAEN-ECE-D
 Navy: HQ NAVFACENGCOM/CODE 04F

4. Fire protection

Except as modified by waiver or by specific criteria from the military departments, fire protection shall conform to the requirements of applicable standards in the current National Fire Codes published by the NFPA. (136) 13-1

Matters pertaining to fire department operations, staffing, and equipment are not covered in this chapter. Fire protection engineering considerations for operations and equipment are covered in other publications. (138) 13-1

New facilities shall be fire-resistant or noncombustible construction separated from other areas by fire-rated walls or partitions. Existing C-E facilities of combustible construction shall be replaced with noncombustible construction

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whenever practical. (136) 13-7

Fire protection criteria for C-E facilities are summarized in several tables under Policy/SOP on the following pages. Since requirements may differ between military departments, the source of each table is referenced.

5. Life safety (136) 13-1

Means of egress for both new and existing facilities shall conform to the requirements of applicable standards contained in the Life Safety Code, NFPA 101. Fundamental Life Safety Code requirements include--

- a. Enough exits--Buildings designed for human occupancy shall provide enough exits to allow escape in an emergency. Exits shall be designed to depend on more than one safeguard.
 - b. Exit specifications--The type, number, location and travel distance, and capacity of exits shall be based on the type of occupancy, number of occupants, available fire protection, and general specifications for the building.
 - c. Exit arrangement--Free and unobstructed egress is the underlying principle of exit arrangement.
 - d. Exit identification--Exits and exit access shall be clearly visible and conspicuous to reduce the danger of panic in an emergency. Adequate, reliable illumination shall be provided for the means of egress.
 - e. Multiple means of egress--Because any single means of egress can become blocked in an emergency, an alternative shall be provided. This requirement uses the concept of redundant safeguards--a crucial underlying principle of the Life Safety Code.
 - f. Protection systems in addition to exits--Buildings shall be designed with protection features (such as sprinklers and smoke partitions) that buy time for proper exiting in an emergency.
 - g. Fire alarms--When building size or arrangement is such that a fire itself would not provide enough advance warning to allow safe exit, fire alarms shall be provided.
 - h. Protection of vertical openings--Buildings shall protect against the spread of fire, smoke, or fumes to allow safe exit.
1. The Life Safety Code does not address general fire protection, general building construction, protection from careless acts, personal injury during normal use, or the

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preservation of property.

6. System analysis

MIL-STD-882, System Safety Program Requirements, shall be incorporated into the design of all construction projects and major alterations. In the planning stages for any project and any requests for funding, the determination must be made, based on a complete analysis, what fire safety features will be included in the project. This analysis shall use Fire Protection Symbols for Fire Risk Analysis (NFPA 174) diagrams. The result of this analysis will include the type number, degree of protection afforded, extent of protection required, and cost factors to be included in the project cost estimation and requests for funding. Failure to include this analysis will result in an incomplete project description and jeopardize approval. If the project is allowed to proceed, it will result in construction, alteration, or modification that fails to meet Federal, DOD, or Air Force required criteria. (138) 13-4

7. Architect-engineer (AE) services

Some military departments require AE firms to be proficient in fire protection engineering. AE contracts shall include a provision requiring sound engineering practice, and documented analysis and justification/rationale in the design of fire safety features or their exclusion. Before awarding design or project contracts, AEs shall be required to show competence in this field, including the design of installed fire safety features as an integral component of their own firm or through a recognized fire protection engineering consultant. (138) 13-2

8. C-E equipment defined

As used in this chapter, "communications-electronic equipment" means communication system hardware that provides:

- Transmission
- Receiving
- Control
- Switching

operations of the Defense Communication System (DCS). This includes the:

- Electrical power supply system
- Uninterrupted power source (UPS)
- Batteries
- Standby generators

essential to the communication mission.

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Table 1 TYPES OF CONSTRUCTION--FIRE RESISTANCE REQUIREMENTS (138) 13-8

Building element	Noncombustible				Combustible*				
	Type I		Type II		Type III		Type IV	Type V	
	Fire-Resistive	Fire-Resistive	1-hr	N**	1-hr	N	HT**	1-hr	N
Exterior bearing walls	4	4	1	N	4	4	4	1	N
Interior bearing walls	3	2	1	N	1	N	1	1	N
Exterior nonbearing walls	4	4	1	N	4	4	4	1	N
Structural frame***	3	2	1	N	1	N	1 or	1	N
Partitions--permanent	1 [†]	1 [†]	1	N	1	N	HT	1	1
Shaft enclosures	2	2	1	N	1	1	1	1	1
Floors	2	2	1	N	1	N	HT	1	N
Roofs	2	1	1	N	1	N	HT	1	N

*Not permitted in new C-E facilities. When existing C-E facilities are retrofitted, noncombustible construction shall be used. (AFM 88-15 Nov 83)

**N--No general requirements for fire resistance. HT--Heavy timber.
 ***Structural frame elements in the exterior wall shall be protected against external fire exposure as required for exterior bearing walls for the structural frame, whichever is greater.

[†]Fire-retardant treated wood may be used in the assembly, provided fire-resistance requirements are maintained.

policy/sop

Table 2 FIRE PROTECTION CRITERIA FOR COMMUNICATIONS-ELECTRONICS FACILITIES (139) 2-27

Protection Systems Areas		Automatic Water-Sprinkler System	Automatic Smoke-Detection and Alarm System	Automatic Halon 1301 System	Portable Fire-Extinguisher	
C-E Equip-ment area	Combustible environment*	<u>Required</u> DOD 4270.1M Para 13-4.10B	<u>Required</u> DOD 4270.1M Para 13-4.10D(1) & NFPA 72E, Para 2-6.5	<u>Conditional**</u> DOD 4270.1M Para 13-4.10C(1) & NFPA 75, Para 5-3	<u>Class C (Electric)</u> <u>Required</u> Halon or CO ₂	<u>Class A (Material)</u> <u>Required</u> Water type
	Noncombustible environment	<u>Not Required</u> DOD 4270.1M Para 13-4.10B	<u>Required</u> DOD 4270.1M Para 13-4.10D(1) & NFPA 72E, Para 2-6.5	<u>Conditional**</u> DOD 4270.1M Para 13-4.10C(1) & NFPA 75, Para 5-3	NFPA 75, Para 5-1.1	NFPA 75, Para 5-1.2
Under raised floor area		<u>Not Required</u>	<u>Required</u> DOD 4270.1M Para 13-4.10D(2) & NFPA 75, Para 2-5.3(a)	<u>Required</u> When used as air plenum with exposed, nonmetallic sheathed cables-- DOD 4270.1M Para 13-4.10C(2)	<u>Required</u> To be available in the space above or nearby, floor lifters required.	
Records storage area***		<u>Required</u> Except for records contained in closed metal files or cabinets-- DOD 4270.1M Para 13-4.10B(4)	<u>Required</u> DOD 4270.1M Para 13-4.10D(1) & NFPA 72E, Para 2-6.5	<u>Not Required</u> But optional if vital, nonduplicate, magnetic tapes stored DOD 4270.1M Para 13-4.10C(1)	<u>Required</u> Light hazard, Class A, requires that maximum distance to fire extinguisher: 75 feet. NFPA 75, Para 606.2.3	
Administration, maintenance, supply operations***		<u>Conditional</u> Required when combustibles present with possible loss minimum of \$250,000, mission interruption, or loss of life--DOD 4270.1M, Para 13-2.1(e,f,g,h,i)	<u>Required</u> DOD 4270.1M Para 13-2.3 and NFPA 72E, Para 2-6.5	<u>Not Required</u> DOD 4270.1M Para 13-4.10C(1)	<u>Required</u> Portable extinguishers shall be available nearby. Maximum distance to fire extinguisher: 75 feet--NFPA 75, Para 6-6.2.3.	

*Not permitted in new C-E facilities. When existing C-E facilities are retrofitted, noncombustible construction shall be used.

**To be determined by HQ, USACC.

***Spaces should be placed outside of equipment area if possible. If put inside of C-E equipment area, the space shall be treated the same as an equipment area.

policy/sop

Table 3 UNIFORM BUILDING CODE--BASIC ALLOWABLE FLOOR AREA FOR BUILDINGS (SQ FT)

Occupancy*	Construction Types								
	I	II			III		IV	V	
	FR	FR	I-hr	N	I-hr	N	HT	I-hr	N
A-1	Unlimited	29,900	Not permitted						
A) 2-2.1	Unlimited	29,900	13,500	Not permitted	13,500	Not permitted	13,500	10,500	Not permitted
A) 3-4	Unlimited	29,900	13,500	9,100	13,500	9,100	13,500	10,500	6,000
B) 1-2-3*	Unlimited	39,900	18,000	12,000	18,000	12,000	18,000	14,000	8,000
B-4	Unlimited	59,900	27,000	18,000	27,000	18,000	27,000	21,000	12,000
E	Unlimited	45,200	20,200	13,500	20,200	13,500	20,200	15,700	9,100
H) 1-2**	15,000	12,400	5,600	3,700	5,600	3,700	5,600	4,400	2,500
H) 3-4-5	Unlimited	24,800	11,200	7,500	11,200	7,500	11,200	8,800	5,100
I) 1-2	Unlimited	15,100	6,800	Not permitted	6,800	Not permitted	6,800	5,200	Not permitted
I-3	Unlimited	15,100	Not permitted***						
M†	See Chapter II, UBC								
R-1	Unlimited	29,900	13,500	9,100††	13,500	9,100††	13,500	10,500	6,000††
R-3	Unlimited								

Notes: no requirements for fire

N--no requirements for fire resistance.
 FR--fire resistive.
 HT--heavy timber.
 Uniform Building Code, 1982 Edition.

*For open parking garages, see Section 709, UBC.
 **See Section 903, UBC.

***See Section 1002(b), UBC.

†For agricultural buildings, see also Appendix Chapter 11, UBC.
 ††For limitations and exceptions, see Section 1202(b), UBC.

* See Tables for Descriptions of Occupancy.

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Table 4 UNIFORM BUILDING CODE--MAXIMUM HEIGHT OF BUILDINGS

Occupancy*	Construction Types								
	I	II			III		IV	V	
	FR	FR	1-hr	N	1-hr	N	HT	1-hr	N
	Maximum Height in Feet								
	Unlimited	160	65	55	65	55	65	50	40
	Maximum Height in Stories								
	A-1	Unlimited	4	Not permitted					
A) 2-2.1	Unlimited	4	2	Not permitted	2	Not permitted	2	2	Not permitted
A) 3-4	Unlimited	12	2	1	2	1	2	2	1
B) 1-2-3*	Unlimited	12	4	2	4	2	4	3	2
B-4	Unlimited	12	4	2	4	2	4	3	2
E**	Unlimited	4	2**	1	2**	1	2**	2**	1
H-1	Unlimited	2	1	1	1	1	1	1	1
H) 2-3-4-5	Unlimited	5	2	1	2	1	2	2	1
I-1	Unlimited	3	1	Not permitted	1	Not permitted	1	1	Not permitted
I-2	Unlimited	3	2	Not permitted	2	Not permitted	2	2	Not permitted
I-3	Unlimited	2	Not permitted***						
M†	See Chapter 11, UBC								
R-1	Unlimited	12	4	2††	4	2††	4	3	2††
R-3	Unlimited	3	3	3	3	3	3	3	3

N--No requirements for fire resistance.

FR--fire resistive.

HT--heavy timber.

Uniform Building Code, 1982 Edition.

*For open parking garages, see Section 709, UBC.

**See Section 802(c), UBC.

***See Section 1002(b), UBC.

†For agricultural buildings, see also Appendix Chapter 11, UBC.

††For limitations and exceptions, see Section 1202(b), UBC.

* See Tables for Descriptions of Occupancy.

policy/ sop

Table 5 UNIFORM BUILDING CODE DESCRIPTIONS OF OCCUPANCY

Group	Description of Occupancy
A See also Section 602, UBC	1--Any assembly building with a stage and an occupant load of 1000 or more in the building.
	2--Any building or portion of a building having an assembly room with an occupant load of less than 1000 and a stage. 2.1--Any building or portion of a building having an assembly room with an occupant load of 300 or more without a stage, including buildings used for educational purposes and not classed as a Group E or B, Division 2 occupancy.
	3--Any building or portion of a building having an assembly room with an occupant load of less than 300 without a stage, including buildings used for educational purposes and not classed as a Group E or B, Division 2 occupancy.
	4--Stadiums, reviewing stands and amusement park structures not included within other Group A occupancies.
B See also Section 702, UBC	1--Gasoline service stations, garages where no repair work is done except exchange of parts and maintenance requiring no open flame, welding, or use of flammable liquids. 2--Drinking and dining establishments having an occupant load of less than 50, wholesale and retail stores, office buildings, printing plants, municipal police and fire stations, factories, and workshops using material not highly flammable or combustible, storage and sales rooms for combustible goods, paint stores without bulk handling. Buildings or portions of buildings that have rooms used for educational purposes, beyond the 12th grade, with less than 50 occupants in any room.
B (Cont'd)	3--Aircraft hangars where no repair work is done except exchange of parts and maintenance requiring no open flame, welding, or the use of highly flammable liquids. Open parking garages (for requirements, See Section 709, UBC) Heliports 4--Ice plants, power plants, pumping plants, cold storage, and creameries Factories and workshops using noncombustible and nonexplosive materials Storage and salesrooms of noncombustible and nonexplosive materials
E See also Section 802, UBC	1--Any building used for educational purposes through the 12th grade by 50 or more persons for more than 12 hours per week or 4 hours in any one day. 2--Any building used for educational purposes through the 12th grade by less than 50 persons for more than 12 hours per week or 4 hours in any one day 3--Any building used for day-care purposes for more than six children

(Continued on next page)

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UNIFORM BUILDING CODE DESCRIPTIONS OF OCCUPANCY (CONT'D)

Group	Description of Occupancy
H See also Sections 902 and 903, UBC	1--Storage, handling, use or sale of hazardous and highly flammable or explosive materials other than flammable liquids (See also Section 901 [(a)], Division 1, UBC) 2--Storage, handling, use or sale of Classes I, II and III--A liquids dry cleaning plants using Class I, II or III--A liquids; paint stores with bulk handling, paint shops and spray-painting rooms and shops (See also Section 901[(a)], Division 2, UBC) 3--Woodworking establishments, planing mills, box factories, buffing rooms for tire-rebuilding plants and picking rooms; shops, factories or warehouses where loose, combustible fibers or dust are manufactured, processed, generated, or stored; pin-refinishing rooms. 4--Repair garages not classified as a Group B, Division 1 occupancy 5--Aircraft repair hangars
I See also Section 1002, UBC	1--Nurseries for the full-time care of children under the age of six (each accommodating more than five persons) Hospitals, sanitariums, nursing homes with nonambulatory patients and similar buildings (each accommodating more than five persons) 2--Nursing homes for ambulatory patients, homes for children six years of age or over (each accommodating more than five persons) 3--Mental hospitals, mental sanitariums, prisons, reformatories and buildings in which inmates' personal liberties are similarly restrained
M²	1--Private garages, carports, sheds and agricultural buildings (See also Section 1101, Division 1, UBC) 2--Fences over 6 feet high, tanks, and towers
R See also Section 1202, UBC	1--Hotels and apartment houses Convents and monasteries (each accommodating more than 10 persons) 3--Dwellings and lodging houses

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Table 6A EXPOSURE CLASSIFICATION FOR THE SEPARATION OF STRUCTURES (138) 13-11

EXPOSURE CLASSIFICATION								
Building Construction			Fire Area of Building sq ft (m ²) per Floor					
Walls	Height	Roof and Floor**	Hazard due to Occupancy*	1500-2500 (140-230)	2500-5000 (230-460)	5000-10,000 (460-930)	10,000-20,000 (930-1860)	Over 20,000 (1860)
Load-bearing masonry	Multi-story	C	Extra Ordinary 2,3 Ordinary 1 Light	C C D D	B C D D	B B C D	A B B B	A B B B
Load-bearing masonry	One story***	C	Extra Ordinary 2,3 Ordinary 1 Light	C C D D	B C D D	B B C D	B B B C	B B B C
Comb†	Multi-story	NC or C	Extra Ordinary 2,3 Ordinary 1 Light	B B B C	B B B B	A B B B	A A B B	A A B B
Comb†	One story***	NC or C	Extra Ordinary 2,3 Ordinary 1 Light	B C C D	B B B C	B B B C	B B B B	A A B B
NC panel†† on steel frame. Nonload-bearing masonry, concrete, or brick	Multi-story		Extra Ordinary 2,3 Ordinary 1 Light	C C D D	B C D D	B C D D	B B C D	B B C C
NC panel†† on steel frame. Nonload-bearing masonry concrete or brick	One story***	NC or C	Extra Ordinary 2,3 Ordinary 1 Light	C C D D	C C D D	B B D D	B B D D	B B D D
Load-bearing masonry or concrete	Single or multi-story	NC	Extra Ordinary 2,3 Ordinary 1 Light	D D D D	D D D D	C C D D	C C D D	C C D D

(Continued on next page)

policy / sop

Table 6B SEPARATION OF STRUCTURES

New building (wall surface)	Separation Distances in Feet (Meters)							
	Exposure							
	No Sprinklers				Sprinklers			
	A	B	C	D	A	B	C	D
Wood								
Asphalt shingle	150(46)	110(33)	90(27)	70(21)	55(17)	35(11)	25(8)	15(5)
Painted or unpainted	95(29)	65(20)	50(15)	40(12)	35(11)	20(6)	5(2)	
Steel/aluminum siding	95(29)	65(20)	50(15)	40(12)	30(9)	20(6)	10(3)	
Stucco or asbestos shingle	75(23)	45(14)	35(11)	25(7)	20(6)	10(3)	20(6)	
Brick or stone veneer	60(18)	40(12)	25(8)	15(5)				
Panel on steel frame [§]								
Insulated aluminum	95(29)	70(21)	50(15)	35(11)	45(14)	30(9)	20(6)	10(3)
Plastic, fiberglass panel								
Asphalt-coated metal	75(23)	45(14)	35(11)	25(8)	40(12)	25(8)	15(5)	10(3)
Insulated steel panel	65(20)	40(12)	30(9)	20(6)	35(11)	20(6)	10(3)	5(2)
Protected metal, plain	55(17)	35(11)	25(8)	15(5)	30(9)	15(5)	5(2)	
Asbestos panel	45(14)	30(9)	20(6)	10(3)	20(6)	10(3)	5(2)	
Masonry or concrete								
Concrete block on exposed steel frame [§]	20(6)	15(5)	10(3)	0	20(6)	15(5)	10(3)	

Definitions: C = combustible, NC = noncombustible.
 Examples of C: plank on timber; plank on steel; board on joist.

*Based on Sprinkler Protection Classifications, as defined in this chapter.
 **If floors and roof are of different construction, use worst case.

***One-story buildings 25 ft (8 m) or higher shall be considered as multistory.

†Includes old-type asphalt-coated metal buildings.

††NC panel wall may be protected metal, plain or corrugated, with or without insulation, asbestos-cement, or similar NC materials on steel frame.

§When there are no outside sprinklers, wired glass should be installed in window openings when the separation distance is within 65 ft (20 m) for a Class A exposure, 50 ft (15 m) for a Class B exposure, 40 ft (12 m) for a Class C exposure, and 25 ft (8 m) for a Class D exposure.

Notes: Consider fire walls, if any, when determining area.
 For explosive ordnance materials, refer to DOD 5154.4S--DOD Ammunition and Explosive Safety Standards.
 This table was adapted from Factory Mutual Loss Prevention Data Sheets based on theoretical radiation calculations.

policy/sop

Table 7 WATER DEMANDS FOR SPRINKLERED FACILITIES (137) 8-7-4

Sprinkler Classification	Sprinklers			
	Design Density,* (gal/min)/sq ft (mL/m ² sec)	Design Area,** sq ft (m ²)	Hose, gal/min (L/sec)	Duration of Supply (min)
Light hazard	0.10 (70)	3000 (280)	250 (15)	45
Ordinary hazard Group 1	0.15 (100)	3000 (280)	500 (30)	60
Ordinary hazard Group 2	0.20 (140)	3000 (280)	500 (30)	75
Ordinary hazard Group 3	0.25 (170)	3000 (280)	500 (30)	90
Extra hazard	0.35 (240)	3000 (280)	750 (50)	105
Ordinance plants (exposed powder area)	0.50 (340)	Entire area	750 (50)	45
Rubber tire storage	0.60 (410)	3000 (280)	750 (50)	150
Missile assembly	0.25 (170)	Entire area	500 (30)	45

*These densities may be reduced to a minimum of NFPA No. 13 requirements for 3000 sq ft (280 m²) at the discretion of the Division Fire Protection Engineer if fire loading or interior finish warrants.

**For dry pipe systems, increase design area by 30 percent.

Table 8 WATER DEMANDS FOR UNSPRINKLERED FACILITIES (137) 8-7-4

Sprinkler Classification	Hose Streams gal/min (L/sec) at 20 lb/sq in. (140 kPa) Residual Pressure	Duration (min)
Light hazard	750-1500 (50-100)	60-120
Ordinary hazard Group 1	1000-2000 (60-125)	90-150
Ordinary hazard Group 2	1500-3000 (100-200)	90-150
Ordinary hazard Group 3	2000-4000 (125-250)	120-180
Extra hazard	2500-5000 (150-300)	150-240

Issues and assumptions**Fire protection construction criteria**

Questions may arise regarding policy for providing fire protection at C-E facilities. The following factors must be considered in the analysis to determine which fire safety features will be included in the design.

1. Requirements of OSHA regulations and Using Service Occupational Safety and Health Standards.
2. DOD requirements.
3. Uniform Building Codes requirements.
4. National Fire Code requirements.
5. Whether omission of such features will result in a condition that is a threat to life, to the military department mission, or to either Government or private property.
6. Relative importance of equipment, supplies, and facilities.
7. Relative quantity and essentiality of equipment, supplies, or facilities to be protected compared to the availability of the same type items.
8. The ability to replace supplies and facilities including consideration of replacement time, manpower, materials, and cost.
9. Potential severity of fire damage due to the inherent hazard of the structure, stored materials, equipment, or processes.
10. Size of the structure and value of the materials, processes, or equipment as related to the fire protection available from local fire fighting resources.
11. Permanent or temporary use of base, building, or facility under consideration.
12. Whether protection is required for survivability or local conflagration hazard. (138) 13-5

For example, a weighted judgment must be made, on a case-by-case basis, whether portable fire extinguishing equipment will be good enough for facilities under continuous surveillance (as permitted by paragraph 4-2f, AR 420-90) or whether a Halon 1301 total flooding system is justified (under provisions of paragraph 13-4.10C, DOD 4270.1M). This judgment is based on mission criticality, equipment value, distance to an organized fire protection agency, and fire hazard for each facility. Although Halon 1301 systems are highly effective for electrical fires, their cost (about one dollar per cubic foot of space protected) is a significant expense.

Issues and assumptions

The decision to specify a Halon 1301 total flooding system for a given facility will be made by the headquarters of the using service on a case-by-case basis. Specific guidance and decisions of the military departments will be promulgated by individual project and system construction criteria, or by action on recommendations submitted by subordinate commands to the headquarters listed under Policy/SOP.

requirements	criteria	commentary
FIRE PROTECTION 1. Fire protection classifications	1.a. Occupancy classifications (135) 4-1 Subject to the authority with jurisdiction, buildings and structures are classified as follows: • Assembly • Educational • Health care • Detention/correctional • Residential • Mercantile • Business • Industrial • Storage • Unusual structures • Mixed occupancies. For fire protection, many DCS facilities are classified as "business." When "manufacture" operations are housed in C-E facilities, these areas are classified as "industrial." When DCS facilities or parts of facilities are underground or windowless, they are classified as "unusual structures." When two or more classes of occupancy occur in the same facility, it is classified as "mixed occupancies." b. Hazard of contents classification (135) 4-2 The hazard of contents shall be the relative danger of (1) the start and spread of fire, (2) smoke or gases generated, and (3) explosion or other occurrence potentially endangering the lives and safety of the building occupants. When the flame spread rating of the interior finish or other features of the structure present a hazard greater than the hazard of contents, the greater degree of hazard shall govern. When different degrees of hazard for contents exist in different parts of a building or structure, the most hazardous shall govern the classification. "Hazard of contents" shall be determined by the authority with jurisdiction based on the contents' character and the processes or operations conducted in the structure and classified as follows: • Low hazard • Ordinary hazard • High hazard For fire protection, typical DCS facilities are classified as "ordinary hazard" using this system. These	

requirements	criteria	commentary
	classifications do not apply to sprinkler protection classifications (described next). c. Sprinkler protection classifications (177) NFPA 13 Occupancy classifications for sprinkler systems relate to sprinkler installations and their water supplies only. They are not intended to be a general classification of occupancy hazards. Classifications include: • Light hazard • Ordinary hazard - Group 1 - Group 2 - Group 3 • Extra hazard For fire protection, typical DCS facilities are classified as "light hazard" using sprinkler protection classifications. Occupancy in a lower hazard category may warrant consideration at a higher level if more than the usual fire loading is associated with the occupancy. Fire loading may be expressed in two ways: pounds of combustible material per square foot of floor area or British thermal units (Btu) per square foot of floor area. (138) 13-9 d. Construction classifications (138) 13-7 Construction classifications are based on the Uniform Building Code and NFPA 220. Table 1 summarizes the required fire resistance rating for various building components in construction Types I through V. New DCS facilities to house electronic equipment shall be fire-resistant or noncombustible construction. Electronic equipment installations shall be separated from other occupancies by fire-rated walls or partitions (see the table on required building separations). Existing combustible construction shall be replaced with noncombustible construction and separated from other occupancies by fire-rated walls or partitions whenever practical. (136) 13-7 Fire-resistive construction (Type I-UBC): Buildings or areas inside buildings, such as vaults, that are required to prevent outside fires from destroying or damaging the contents. Protected noncombustible construction (Type II-UBC): Buildings exceeding three stories high. Noncombustible construction (Type III-UBC): All other	

requirements	criteria	commentary
2. Building configurations for fire protection	C-E facilities not listed above under Fire Resistive or Protected Noncombustible Construction. Uniform Building Code--Types of Construction together with NFPA 220--Types of Construction form the basis for Table 1 under Policy/SOP. See also Tables 10 and 11 under Guidance. 2.a. Allowable fire areas and height limitations Allowable fire areas and height limitations shall conform to provisions in the latest edition of the Uniform Building Code. (187) 2-4 See Tables 3 and 4 under Policy/SOP for UBC tables of area and height limitations. See Guidance for additional information with respect to using these tables. The maximum fire area (area between fire walls) and height of any building shall not exceed the areas and heights in Tables 3 and 4 for the type of construction and occupancy. Interior fire barriers shall be provided to restrict interior fire spread both horizontally and vertically. Fire barriers such as horizontal fire cutoffs, including fire doors, vertical fire cutoffs, and fire stopping, shall be used to subdivide large structures into separate fire areas and to separate hazardous occupancies and areas from the rest of the building. The proper enclosure of all vertical openings, including stairways, elevator shafts, chases, and ducts, is important in preventing or retarding vertical fire spread. Where cables, conduit, telephone wires, or ducts penetrate floors or fire cut-offs, fire stops shall be provided. The material used for fire stops shall maintain the ratings for fire resistance. (137) 8-2-8 b. Building separation and exposure protection Enough separation of buildings and structures is required to prevent fire from spreading by radiated or convected heat, direct contact, flames, or flying brands. The minimum distances between buildings shall be in accordance with the second table. The necessary distances vary, depending on the expected intensity of the exposure fire, total heat produced, shielding of intervening walls, exposed building height, and the construction and protection of each building. The minimum distances shall be used whenever space is available. However, for fire resistant construction with or without openings, the separation distance may be substantially decreased if the requirements in NFPA 80A, Protection Against Exposure Fires, are met. (187) 2-4	

requirements	criteria	commentary
	The spacing for structures is based on the exposure classification given in Table 6A. The separation of structures based on this classification is given in Table 6B. Use of Tables 6A and 6B. The required clearances between structures should be determined by applying Table 6B. First, determine an exposure classification for the exposing building from Table 6A. That classification A, B, C, or D is then used in Table 6B to determine a separation distance based on the exposed wall surface. Separation distances are governed by the building with the greater hazard, not by which is existing and which is planned. Therefore, in some cases, it will be necessary to determine separation distances for both buildings and choose the larger. Rules for the use of the Tables. Rule 1: One building has a sprinkler system and the other does not. Use Table 6A for the unsprinklered building to determine exposure classification and then use Table 6B for the new building to determine the distance. Rule 2: Both buildings, either sprinklered or unsprinklered. Use Table 6A for both buildings to determine the highest exposure classification and then use Table 6B for the new building to determine the distance. Rule 3: No separation is required in the following situations: (a) Both buildings have automatic sprinklers and at least one building has a 2-hour (or greater) masonry parapeted fire wall. (b) When the taller building has automatic sprinklers and a 2-hour (or greater) masonry parapeted blank fire-rated wall. (c) When the taller building has a 4-hour (or greater) masonry free standing parapeted blank fire-rated wall. (d) When both the buildings have 2-hour (or greater) masonry parapeted blank fire-rated walls, even though they are not free standing. (138) 13-9 Relocatable prefabricated structures shall be separated in accordance with requirements for permanent buildings. (187) 2-4	

requirements	criteria	commentary
3. Recommended materials for fire protection	3.a. Fire protection of constructed elements See Tables 1 through 6 under Policy/SOP for fire protection of constructed elements. b. Fire-rated walls (including doors and dampers) Provide firewalls, fire partitions, and smoke partitions where required. c. Interior finishes An interior finish is defined as the material of walls, ceilings, wainscoting, and other inside surfaces of a building. It includes other interior surfacing materials applied to the walls, movable partitions, and ceilings. Exposed insulation and acoustical materials are considered interior finishes, as well. Interior finishes, along with structural fire resistance and contents hazard, are the main elements in determining building fire potential. (137) 8-2-8	
4. Fire protection systems	4.a. Detection systems Detection systems shall provide maximum fire protection for personnel and equipment consistent with the facility's function. Detection systems should activate local evacuation alarms and extinguishing systems, and transmit signals to the fire response force. (137) 8-9-3 1) Heat-activated devices 2) Products of combustion devices. See automatic detection and alarm system requirements for C-E facilities under Guidance. b. Notification systems This section covers fire alarms commonly used to signal the presence of fire to (1) building occupants to permit prompt evacuation or other appropriate actions; (2) fire department and other alarm communication centers as required for dispatch of fire fighting operations and emergency actions; and (3) actuate automatic fire suppression equipment and smoke control.	

requirements	criteria	commentary
	Manual evacuation alarm systems and exterior fire reporting systems shall be provided at Army activities in accordance with DOD Construction Criteria Manual 4270.1-M, and Army Regulation No. 420-90, <u>Fire Prevention and Protection</u>. (187) 8-1 Notification systems: 1. System classification 2. Manual alarms 3. Automatic alarms 4. Signaling devices 5. Municipal fire alarm systems C. Suppression systems 1. Automatic extinguishing systems The following factors shall be considered when determining and justifying the need for automatic sprinkler installation in a given facility: • Life safety and occupancy hazard risks • Exterior fire exposures presented by the facility • Strategic or tactical importance of the facility or supplies housed therein • Quantity of supplies or facilities involved relative to those available • Ability to replace the facility and contents • Fire potential of the operations inside the facility • Size of facility in relation to available firefighting resources and values of the materials or processes. In addition to the AFM 88-2 requirement for sprinkler protection in certain facilities or areas inside, closed head "wet or dry" pipe automatic sprinkler systems will be installed in structures of the occupancies listed below. (Installations in areas not normally heated or when otherwise desirable due to climate shall be of the "dry" pipe type.) Warehouses, sheds (including transit and pier types), and similar storage-type buildings that contain combustible materials or supplies identified as any of the following:	

requirements	criteria	commentary
	• Critical • Severe fire hazard • Expensive • Vital to mission • 4000 square feet or greater. Technical, industrial, and commercial type buildings, including hangars, shops, and laboratories used for production, repair, experimental testing, electronics overhaul, or other processes, services, or equipment identified as any of the following: • Critical • Severe fire hazard • Expensive • Vital to mission. Combustible construction facilities with fire areas greater than 8000 square feet (740 square meters). Windowless or underground structures. Storage and other building areas made of noncombustible or fire-resistant material where moderate or large volumes of combustible materials are stored or which constitute fire or explosion hazards. These areas shall also be separated from areas without sprinklers by fire partitions that have at least a 1-hour fire-resistance rating and by fire doors of comparable rating at openings. Buildings in which large amounts of critical equipment or material are exposed by combustible construction, storage, or hazardous operations. Critical equipment or material includes training devices; electronics; photographic, optical, or computer data processing; aircraft engine vital parts; and similar objects used for operations, training, manufacture, assembly, or repair. Sprinklered areas shall be separated from unsprinklered areas by partitions that have a minimum fire-resistance rating of 2 hours. (138) 13-22 2. Manual extinguishing systems (137) 8-8-8 Standpipe systems--Installation of 2 1/2-inch (64-millimeter) standpipe systems shall be in accordance with NFPA 14. Standpipe with 2 1/2-inch (64-millimeter) hose outlets (without hose) shall be provided in stair towers of buildings greater than three stories high.	

requirements	criteria	commentary
	Portable extinguishers. Portable extinguishers shall be provided in accordance with NFPA 10, Portable Fire Extinguishers. Portable fire extinguishers are not required in public quarters. 3. Water supply for fire protection. Fire protection water supply requirements are in AFM 88-10 and NAVFAC DM-8 (137). When additional water supplies (that is, dedicated fire protection pumps and storage tanks) are required, they shall be completely supervised. (138) 13-19 See Tables 7 and 8 for a summary of water supply requirements for fire protection.	

requirements	criteria	commentary																					
LIFE SAFETY 1. Means of egress (186)	1.a. Occupant load The occupant load is the total number of persons who may occupy C-E facilities or parts of such facilities at any one time. The means of egress for all floors, balconies, tiers, or other occupied spaces shall have a capacity great enough for its occupant load. Exit capacity must be provided for at least the occupant load determined by dividing the gross area (area inside the exterior walls) of the facility by the occupant load factor for C-E facilities. The occupant load factor shall be no less than one person per 100 square feet of gross floor area. (Based on "Business Occupancy," NFPA 101.) b. Exit capacities Unit of exit width 1 unit = 22 inches Fractions > 12 inches = 1/2 unit Fractions < 12 inches are not counted. Exit capacity per unit of exit component width Doors: 1 unit for 100 persons Stairs: 1 unit for 60 persons <table border="1"> <tr> <th>Ramps:</th><th>Class A</th><th>Class B</th></tr> <tr> <td>Minimum width</td><td>44 inches</td><td>30 inches</td></tr> <tr> <td>Maximum slope</td><td>1 in 10</td><td>1 in 8</td></tr> <tr> <td>Maximum height between landings</td><td>No limit</td><td>12 feet</td></tr> <tr> <td>Capacity in persons per unit of exit width</td><td></td><td></td></tr> <tr> <td>Down</td><td>100</td><td>100</td></tr> <tr> <td>Up 100</td><td>60</td><td></td></tr> </table> c. Number of exits Each facility shall have no less than two exits readily accessible at all times from every part of every floor. A single exit is allowed from a room or area if all the following conditions are met: • Occupant load less than 100 • Direct access to a street or open exterior area at ground level • Total travel distance no more than 100 feet from anywhere in a room to the outside • No stairs in the exit travel more than 15 feet high • All stairways completely enclosed with no door openings between the stair enclosure and rest of the building.	Ramps:	Class A	Class B	Minimum width	44 inches	30 inches	Maximum slope	1 in 10	1 in 8	Maximum height between landings	No limit	12 feet	Capacity in persons per unit of exit width			Down	100	100	Up 100	60		
Ramps:	Class A	Class B																					
Minimum width	44 inches	30 inches																					
Maximum slope	1 in 10	1 in 8																					
Maximum height between landings	No limit	12 feet																					
Capacity in persons per unit of exit width																							
Down	100	100																					
Up 100	60																						

requirements	criteria	commentary
	When more than one exit is required, at least two of the exits shall be separate and remote from each other and so arranged and constructed as to minimize any possibility of both being blocked by fire or other emergency condition. d. Exit travel distances Required exits must be suitably located to allow access without passage through kitchens, store rooms, restrooms, workrooms, closets, bedrooms, or similar areas that may be locked. Travel distances to exits shall be no more than 200 feet; they may be 300 feet if the facility is protected throughout by an automatic sprinkler system. Travel distance requirements apply to only the first, or nearest, exit from a point in a facility; this does not mean all exits must be within the required travel distance. No dead-end corridor shall exceed 50 feet. To measure the exit travel distance-- • Start 1 foot from most remote point • Follow the centerline of the natural path of travel • Maintain 1 foot of clearance around corners and obstructions • Measure stairs in the travel path in the plane of the tread nosing • End at the center of the exit. For individual rooms with an occupant load no greater than 6 persons, travel distance to exits shall be measured from the doors of such rooms, provided the path of travel from any point in the room to the room door does not exceed 50 feet. e. Exit components Doors The maximum single door leaf width in a doorway is 48 inches. The floor level shall be substantially level on each side of the door for a distance equal to the widest door. All doors used in a means of egress shall be the side-hinged, swinging type. Doors shall swing in the direction of exit travel-- • When used in an exit • When serving in a high hazard area • When serving an occupant load of 50 or greater.	

requirements	criteria	commentary
	Projection of any door in a means of egress shall not reduce the effective width of an aisle, passageway, stair, or stair landing to less than one-half its required width. When fully open, the door shall project no more than 3-1/2 inches into the required width of a stair or stair landing and no more than 7 inches into the required width of an aisle or passageway. The force required to fully open any door in the means of egress shall not exceed 50 pounds applied to the latch style. For a discussion of locks, latches, and alarm devices, see SB2-"Communication Facility Buildings, Exterior Closure and Interior Construction." Exterior stairs Outside stairs may be part of the means of egress if they are permanently installed and comply with all the requirements for inside stairs. Outside stairs must be separated from the building interior under the same conditions as required for enclosure of inside stairs. Door or window openings below or within 10 feet horizontally of stairs or landings must have at least 3/4-hour fire assemblies when a stair serves more than two stories. f. Exit marking Exits shall be marked by signs. Access to exits shall be marked by signs when the exit or way to reach it is not immediately visible to occupants. Any door, passage, or stairway that is neither an exit nor a way of access to an exit, but is located or arranged so that it may be mistaken for an exit, shall be identified by a sign reading "Not an Exit," or by a sign indicating its actual designation such as "To Basement," "Storeroom," or so forth. Every exit sign shall-- • Have the word "EXIT" in legible letters at least 6 inches high with the principal strokes of the letters at least 3/4-inch wide. • Be illuminated by a reliable light source no less than 5 footcandles on the illuminated surface when the building is occupied after dark or when it is not lighted by a natural source.	

requirements	criteria	commentary
2. Areas of refuge	2.a. Horizontal exit This is a passageway to an area of refuge either from one building to another or from one area, through a fire barrier, to another area of refuge in the same building. The area of refuge must be on the same approximate level and must afford safety from fire and smoke. Horizontal exits can be substituted for other exits (stairs, ramps, doors leading outside) if the other exits' capacity will be reduced no lower than half what it would be without the horizontal exits. Fire compartments created by the horizontal exit must have an additional stairway, doorway, or other nonhorizontal exit. Doors in horizontal exits shall have 1-1/2 hour rating and shall swing in the direction of exit travel.	
3. Illumination	3.a. Exit lights Exit illumination shall be continuous during times when occupants require an available means of egress. The means of egress floors shall be illuminated at all points to a value no less than 1 foot-candle measured at the floor. b. Emergency lighting Emergency lighting shall be required when-- • The building is two or more stories high above the level of exit discharge • The occupant load is 100 or greater above or below the level of exit discharge • The occupant load is 1000 or more.	
4. Smoke removal	4.a. Smoke control systems	

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See the applicable table for fire protection criteria for C-E facilities.

1. a. Occupancy classifications (135) 4-1

The classification of occupancy is subject to the authority having jurisdiction. The classifications defined below are from the Life Safety Code, NFPA 101.

To establish the maximum height and allowable area of buildings, the Uniform Building Code (third and fourth tables) must be used. Use of these tables requires knowledge of the Uniform Building Code's descriptions of occupancy (sixth table), which are classified differently than in the Life Safety Code.

Buildings and structures are classified as follows:

1. Assembly

Buildings or parts of buildings used for gatherings of 50 persons or more for deliberation, workshop, entertainment, amusement, or awaiting transportation constitute assembly occupancies. Occupancy of any room or space for assembly by less than 50 persons in a structure and incidental to other such occupancy shall be classed as part of the other occupancy; it is thus subject to the same provisions. Assembly occupancies are defined as--

Class A--1000 persons or more
Class B--300 to 999 persons
Class C--100 to 299 persons.

2. Educational

Educational occupancies include all buildings used for group gatherings of six persons or more for instruction. Educational occupancies include:

Schools (K through 12th grade)
Nursery schools
Kindergartens
Child day-care facilities

In cases for which instruction is incidental to some other occupancy, the provisions governing such other occupancy shall apply.

3. Health care

Health care occupancies are those used for medical or

guidance FIRE PROTECTION/1 Classification

other treatment or care of persons suffering from physical or mental illness, disease, or infirmity, and for the care of infants, convalescents, or infirm aged persons. Health care occupancies provide sleeping facilities for the occupants or are occupied by persons who are mostly incapable of self-preservation because of age, physical or mental disability, or because of security measures not under their control.

Health care occupancies are grouped as--

- Health care facilities
 - Hospitals
 - Nursing homes
- Residential-custodial care
 - Nurseries
 - Homes for the infirm aged
 - Care institutions for the mentally retarded
- Supervisory care facilities
- Ambulatory care facilities

4. Detention and correctional occupancies

Detention and correctional occupancies are those used to house occupants under some degree of restraint or security. These occupancies house persons who are mostly incapable of self-preservation because of security measures not under their control.

5. Residential

Residential occupancies are those in which sleeping accommodations are provided for normal residence and include all buildings designed with sleeping facilities, except those classified under Health Care or Detention and Correctional Occupancies.

Residential occupancies are classed as--

- Hotels/motels
- Apartments
- Dormitories
- Lodging or rooming houses
- One- and two-family dwellings.

6. Mercantile

Mercantile occupancies include stores, markets, and other rooms, buildings, or structures for the display and sale of merchandise. Minor merchandising in buildings predominantly of other occupancies shall be subject to exit requirements for the predominant occupancy.

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7. Business

Business occupancies are those used for the transaction of business (other than that covered under Mercantile), for the keeping of accounts and records, and similar purposes. Included in this group are:

- Doctors' offices
- Dentists' offices
- General offices
- Outpatient clinics (ambulatory)
- College and university instructional buildings, classrooms under 50 persons, and instructional laboratories

Minor office occupancy incidental to operations in another occupancy shall be considered as a part of the predominating occupancy and shall be subject to the provisions applying to that occupancy.

8. Industrial

Industrial occupancies include those in which products of all kinds are made. They are devoted to operations such as processing, assembly, mixing, packaging, finishing or decorating, and repair, including, among others--

- | | |
|-----------------------|---|
| • Laboratories | • Gas plants |
| • Dry cleaning plants | • Refineries |
| • Power plants | • College and university instructional laboratories |
| • Pumping stations | |
| • Laundries | |

9. Storage

Storage includes all structures used primarily for storing or sheltering goods, merchandise, products, vehicles, or animals. Included in this occupancy group are--

- | | |
|------------------------------|-------------------|
| • Warehouses | • Parking garages |
| • Cold storage | • Hangars |
| • Freight terminals | • Grain elevators |
| • Truck and marine terminals | • Barns |
| • Bulk oil storage | • Stables. |

Minor storage incidental to another occupancy shall be treated as part of the other occupancy.

10. Unusual structures

Occupancies in unusual structures include those not properly classified in any of the preceding groups, either because of some function not encompassed or because of some unusual combination of functions necessary to the structure's purpose. Such structures shall conform to the fundamental principles stated in Policy/SOP and to any specific provisions

guidance FIRE PROTECTION/1 Classification

that apply to occupancies in Unusual Structures.

11. Mixed occupancies

Where two or more occupancy classes occur in the same building or structure and are so intermingled that separate safeguards are impractical, means of egress, construction, protection, and other safeguards shall comply with the most restrictive life-safety requirements of the occupancies involved.

b. Hazard of contents classifications

The hazard of contents of any structure shall be classified as low, ordinary, or high in accordance with the following:

- Low-hazard contents shall be classified as those of such low combustibility that no self-propagating fire can occur and that, consequently, the only probable danger requiring emergency exits will be from panic, fumes, smoke, or fire from some external source.
- Ordinary hazard contents shall be classified as those liable to burn with moderate rapidity or to give off a considerable volume of smoke, but from which neither poisonous fumes nor explosions are to be feared in case of fire.
- High-hazard contents shall be classified as those liable to burn with extreme rapidity or from which poisonous fumes or explosions are to be feared in the event of fire.

c. Sprinkler protection classifications (138) 13-Appendix

Typical examples for the types of hazard are listed under each classification. The basic hazard classification of an occupancy does not always categorically define the fire hazard present in all areas of that occupancy. If more hazardous areas exist in a given occupancy, they shall be protected in accordance with the fire protection requirements for the hazard classification of that area. The classification for unlisted occupancies shall be determined from the definitions or by comparison with one of the listed ones.

1. Light-hazard occupancies

These are occupancies or parts of occupancies for which the quantity and combustibility of contents are low and fires with relatively low rates of heat release are expected. Small, scattered amounts of flammable liquids in closed containers are allowable if they do not exceed 5 gallons (20 liters). The following are examples of light hazard occupancies:

- | | |
|---|--------------|
| • Churches and Chapels | • Gymnasiums |
| • Clinics (dental, outpatient) | • Hospitals |
| • Clubs (officer, enlisted personnel, etc.) | • Kitchens |
| | • Mess areas |

guidance	FIRE PROTECTION/1	Classification
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- | | |
|--|---|
| <ul style="list-style-type: none"> • Data processing areas • Disciplinary barracks • Dwellings • Drill halls • Photographic processing areas • Schools | <ul style="list-style-type: none"> • Offices |
|--|---|

2. Ordinary hazard group 1 occupancies

These are occupancies or parts of occupancies for which combustibility is low, the quantity of combustibles is moderate, stockpiles of combustibles do not exceed 8 feet (2.5 meters), and fires with moderate rates of heat release are expected. Modest, scattered amounts of flammable liquids in closed containers are allowable up to about 20 gallons (75 liters). The following are examples of ordinary hazard group 1 occupancies:

- Armories
- Bowling alleys
- Commissaries
- Exchanges
- Forge shops
- Machine shops
- Printing shops (using inks with flashpoints above 100°F [44°C])
- Sheet metal shops
- Shipfitting shops
- Small stores
- Theaters and auditoriums
- Welding shops.

3. Ordinary hazard group 2 occupancies

These are occupancies or parts of occupancies for which the quantity and combustibility of contents is moderate, stockpiles do not exceed 12 feet (4 meters), and fires with moderate rate of heat release are expected. Moderate, scattered amounts of flammable liquids, in closed containers, are allowable in quantities up to about 50 gallons (200 L). Small amounts of flammable liquids may be exposed as required by normal operations. The following are examples of ordinary hazard group 2 occupancies:

- Air rework facilities
- Boiler rooms
- Electrical maintenance shops
- Engine and generator rooms
- Laboratories
- Laundries
- Refrigeration and air compressor rooms
- Switchgear rooms
- Woodworking plants.

guidance	FIRE PROTECTION/1	Classification
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4. Ordinary hazard group 3 occupancies

These are occupancies or parts of occupancies for which the quantity or combustibility of contents is high and fires of a high rate of heat release are expected. Moderate, scattered amounts of flammable liquids in closed containers are allowable up to about 50 gallons (200 liters). Small amounts of flammable liquids may be exposed as required by normal operations. The following are examples of ordinary hazard group 3 occupancies:

- Piers and wharves
- Vehicle repair garages
- Ordnance plants (without exposed powder).

5. Extra-hazard occupancies

These are occupancies or parts of occupancies for which the quantity and combustibility of contents are very high, or for which flammable liquids, dust, lint, or other materials are present and introduce the probability of explosion and rapidly spreading fires with high rates of heat release. The following are examples of extra hazard occupancies:

- Flammable and combustible liquids (not high-piled or high-rack storage)
- Warehouses (not high-piled or high-rack storage).

6. Special occupancies

Special occupancies are facilities or areas that cannot be assigned a specific classification because of special protection requirements. This classification includes, but is not restricted to, the following occupancies:

- Aircraft hangars
- Engine test cells
- Missile assembly
- Ordnance plants (exposed power areas)
- Rubber tire storage
- Warehouses (high-piled or high-rack storage)
- Foam rubber or plastic storage

d. Construction classifications (138) 13-7

Buildings are in one of five major types of construction categories based primarily on the fire resistance of interior and exterior structural support members, walls, floors, and roofs. Construction categories are taken from the International Conference of Building Officials' Uniform Building Code and NFPA 220. Table 9 defines required fire resistances for various building components in each of the categories. The fire resistances are expressed in terms of 1-, 2-, 3-, and 4-hour resistance to fire.

guidance FIRE PROTECTION/1 Classification

1. Type I

All structural members including walls, columns, beams, floors, and roofs are of approved noncombustible or limited-combustible materials. Walls and permanent partitions shall be of noncombustible fire-resistive construction; however, permanent, nonbearing partitions of 1- or 2-hour fire-resistive construction that are not part of a shaft enclosure may have fire-retardant treated wood within the assembly.

2. Type II

Construction that does not qualify for a Type I rating but has structural members including walls, columns, beams, floors, and roofs of approved noncombustible or limited-combustible materials. Subcategories are fire-resistive (F.R.), 1-hour fire-resistive rating, and no fire resistance rating (N). The structural elements in Type II fire-resistive buildings shall be of steel, iron, concrete, or masonry. The structural elements of Type II 1-hour or Type II-N buildings shall be of noncombustible materials. Walls and permanent partitions of Type II-F.R. buildings shall be of noncombustible, fire-resistive construction; however, permanent nonbearing partitions of 1- or 2-hour fire-resistive construction that are not part of a shaft enclosure can have fire-retardant treated wood in the assembly. Type II 1-hour buildings shall be noncombustible construction and shall be 1-hour fire-resistive throughout; however, permanent nonbearing partitions may use fire-retardant treated wood in the assembly, provided fire-resistive requirements are maintained. Walls and permanent partitions of Type II-N buildings shall be of noncombustible materials.

3. Type III

Exterior walls and their structural support members are of approved noncombustible or limited-combustible materials. Interior structural members including walls, columns, beams, floors, and roofs are wholly or partly of wood that has smaller dimensions than required for Type IV construction, or of approved noncombustible, limited-combustible, or other approved combustible materials. Subcategories are 1-hour resistance rating and no fire resistance rating (N). Type III 1-hour buildings shall have 1-hour fire-resistive construction throughout.

4. Type IV

Exterior and interior walls and their structural support members are of approved noncombustible or limited-combustible materials. Interior structural members including columns, beams, arches, floors, and roofs are constructed of either (a) solid or laminated wood, or (b) approved materials that provide a fire resistance rating no less than 1 hour. There will be no concealed spaces. This classification is called "Heavy Timber" construction (See Uniform Building Code).

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5. Type V

Exterior walls, bearing walls, with floors, and roofs and their support members are wholly or partly of wood or other approved combustible material with dimensions smaller than those required for Type IV construction. Subcategories are 1-hour fire resistant rating and no fire resistance rating (N). Note 1: assignment of a fire resistance rating to a given building is based on the fire resistance of its intermediate floors. Note 2: fire-retardant treated wood is plywood lumber impregnated with chemicals which, when tested in accordance with UBC Standard No. 42-1 for 30 minutes, shall have a flame spread no more than 25 and shall show no evidence of progressive combustion. Materials that may be exposed to the weather shall maintain this fire-retardant classification when tested in accordance with UBC Standard No. 32.7 for rain and weathering.

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Table 9 TYPES OF CONSTRUCTION--FIRE-RESISTIVE REQUIREMENTS (UBC)
(in Hours)

Building Element	Type I	Type II Noncombustible			Type III Combustible		Type IV	Type V	
	Fire- Resistive	Fire- Resistive	1-Hr	N	1-Hr	N	HT	1-Hr	N
	4 Sec. 1803 (a)**	4 1903 (a)	1	N	4 2003 (a)	4 2003 (a)	4 2103 (a)	1	N
Exterior bearing walls	4 Sec. 1803 (a)**	4 1903 (a)	1	N	4 2003 (a)	4 2003 (a)	4 2103 (a)	1	N
Interior bearing walls	3	2	1	N	1	N	1	1	N
Exterior nonbearing walls	4 Sec. 1803 (a)	4 1903 (a)	1	N	4 2003 (a)	4 2003 (a)	4 2103 (a)	1	N
Structural frame*	3	2	1	N	1	N	1 or HT	1	N
Partitions--permanent	1***	1***	1***	N	1	N	1 or or HT	1	N
Shaft enclosures	2	2	1	1	1	1	1	1 1706	1 1706
Floors	2	2	1	N	1	N	HT	1	N
Roofs	2 Sec. 1806	1 1906	1 1906	N	1	N	HT	1	N
Exterior doors and windows	Sec. 1803 (b)	1903 (b)	1903 (b)	1903 (b)	2003 (b)	2003 (b)	2103 (b)	2203	2203

Uniform Building Code, 1982 Edition.

N--no general requirements for fire resistance.

HT--heavy timber.

*Structural frame elements in the exterior wall shall be protected against external fire exposure as required for exterior bearing walls or the structural frame, whichever is greater.

**Sections in UBC.

***Fire-retardant treated wood (see Section 407, UBC) may be used in the assembly, provided fire-resistance requirements are maintained. See Sections 1801 and 1901, UBC, respectively.

guidance

NFPA 220--Types of Construction (Table 10) together with Uniform Building Code--Types of Construction form the basis for Table under Policy/SOP. See Table 11 which compares UBC 1982 and NFPA 220.

Table 10 TYPES OF CONSTRUCTION--FIRE-RESISTIVE (NFPA)

	Type I		Type II			Type III		Type IV	Type V	
	443	332	222	111	000	211	200	2HH	111	000
Exterior bearing walls										
Supporting more than one floor, columns or other bearing walls	4	3	2	1	0*	2	2	2	1	0*
Supporting one floor only	4	3	2	1	0*	2	2	2	1	0*
Supporting a roof only	4	3	1	1	0*	2	2	2	1	0*
Interior bearing walls										
Supporting more than one floor, columns or other bearing walls	4	3	2	1	0	1	0	2	1	0
Supporting one floor only	3	2	2	1	0	1	0	1	1	0
Supporting a roof only	3	2	1	1	0	1	0	1	1	0
Columns										
Supporting more than one floor, bearing walls or other columns	4	3	2	1	0	1	0	HH*	1	0
Supporting one floor only	3	2	2	1	0	1	0	HH*	1	0
Supporting a roof only	3	2	1	1	0	1	0	HH*	1	0
Beams, girders, trusses, and arches										
Supporting more than one floor, bearing walls or columns	4	3	2	1	0	1	0	HH*	1	0
Supporting one floor only	3	2	2	1	0	1	0	HH*	1	0
Supporting a roof only	3	2	1	1	0	1	0	HH*	1	0
Floor construction	3	2	2	1	0	1	0	HH*	1	0
Roof construction	2	1-1/2	1	1	0	1	0	HH*	1	0
Exterior nonbearing walls	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*

Type I (3 3 2)

Exterior bearing walls

Structural frame or columns and girders, supporting loads for more than one floor

Floor Construction

Members listed that are permitted to be of approved combustible material.

*Requirements for fire resistance of exterior walls, the provision of spandrel wall sections, and the limitation or protection of wall openings are not related to construction type. They need to be specified in other standards and codes, when appropriate, and may be required in addition to NFPA requirements for the construction type.

**H indicates heavy timber members; see NFPA text for requirements.

guidance FIRE PROTECTION/1 Classification**Table 11** UBC AND NFPA 220 EQUIVALENTS*

UBC 1982	NFPA 220	
Type I, fire-resistive.....	Type I	(444)
	Type I	(332)
Type II, fire-resistive.....	Type II	(222)
Type II, protected non-combustible, 1-hr.....	Type II	(111)
Type II, noncombustible, N.....	Type II	(000)
Type III, protected combustible 1-hr.....	Type III	(211)
Type III, combustible, N.....	Type III	(200)
Type IV, HT.....	Type IV	(2HH)
Type V, protected combustible 1-hr.....	Type V	(111)
Type V, combustible, N.....	Type V	(000)

*These Uniform Building Code Construction Classifications shall be used as equivalent to NFPA 220 requirements when the National Fire Codes refer to NFPA No. 220.

6. Fire protection definitions

These definitions apply to the materials used in building construction, not to furnishings or the contents of buildings, or to the fire hazard evaluation of materials.

- Fire resistance rating is the time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established using the test procedures of Standard Methods of Fire Tests of Building Construction and Materials (NFPA 251 - 1972). The fire resistance of building construction varies with the susceptibility to damage by fire of the building materials used and the degree of fire protection, if any, provided for the structural members.
- Flame spread rating refers to numbers or classifications obtained according to the Method of Test of Surface Burning Characteristics of Building Materials (NFPA 255 - 1972).
- Limited-combustible, as applied to building construction, means a material that does not comply with the definition of noncombustible material and that, in the form used, has a potential heat value not exceeding 3500 British thermal units per pound (8131 kilojoules per kilogram), and

guidance FIRE PROTECTION/2 Building Configurations

complies with one of the following paragraphs (1 or 2). Materials subject to increase in combustibility or flame spread rating beyond the limits established here through the effects of age, moisture, or other atmospheric condition shall be considered combustible.

- Materials that have a structural base of noncombustible material, with a surface not exceeding 1/8 inch (3.2 millimeters) with a flame spread rating no greater than 50.
- Materials for which the form and thickness are other than as described in paragraph 1, and which have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion. They are of such composition that surfaces exposed by cutting through the material on any plane would have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion.

- Minimum hourly fire resistance rating is that degree of fire resistance deemed necessary by the authority with jurisdiction.
- Potential heat value means the average value, in British thermal units per pound, obtained by testing a building material in accordance with the Tentative Method of Test for Potential Heat of Materials in Building Fires (ASTM Special Technical Publication 464, 1970, pp 147-152).
- Noncombustible material is a material which, in the form used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials reported as noncombustible, when tested in accordance with the Standard Method of Test for Noncombustibility of Elementary Materials, ASTM-E 136-73, shall be considered noncombustible. (177)-NFPA 220

2. a. Allowable floor areas. The following sections are taken from Uniform Building Code, 1982 Edition.

Section 505. a. One-story areas. The area of a one-story building shall not exceed the limits set forth in Table 5-C [in UBC] except as provided in Section 506.

- Areas of buildings over one story. The total combined floor area for multistory buildings may be twice that permitted by Table 5-C [in UBC] for one-story buildings, and the floor area of any single story shall not exceed that permitted for a one-story building.
- Mezzanines. Unless considered as a separate story, the floor area

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of all mezzanines shall be included in calculating the allowable floor area of the stories in which the mezzanines are located.

- d. Basements. A basement need not be included in the total allowable area, provided such basement does not qualify as a story nor exceed the area permitted for a one-story building.

- e. Area separation walls. Each portion of a building separated by one or more area separation walls may be considered a separate building, provided the area separation walls meet the following requirements:

1. Area separation walls shall be not less than 4-hour fire-resistive construction in Types I, II-F.R., III and IV buildings and two-hour fire-resistive construction in Types II One-hour, II-N or V buildings. The total width of all openings in such walls shall not exceed 25 percent of the length of the wall in each story. All openings shall be protected by a fire assembly having a 3-hour fire-protection rating in 4-hour fire-resistive walls and 1.5-hour fire-protection rating in 2-hour fire-resistive walls.

2. Area separation walls shall extend to the outer edges of horizontal projecting elements such as balconies, roof overhangs, canopies, marquees or architectural projections.

EXCEPTION: When horizontal projecting elements do not contain concealed spaces, the area separation wall may terminate at the exterior wall.

The exterior walls and the projecting elements above shall be of not less than 1-hour fire-resistive construction for a distance not less than the depth of the projecting elements on both sides of the area separation wall. Openings within such widths shall be protected by fire assemblies having a fire-protection rating of not less than .75 hour.

3. Area separation walls shall extend from the foundation to a point at least 30 inches above the roof.

EXCEPTION: Area separation walls may terminate at the underside of the roof sheathing, deck or slab, provided the roof-ceiling assembly is of at least 2-hour fire-resistive construction.

2. Two-hour area separation walls may terminate at the underside of the roof sheathing, deck or slab, provided:

- a. Where the roof-ceiling framing elements are parallel to the walls, such framing and elements supporting such framing shall be of not less than one-hour fire-resistive construction for a width of not less than 5 feet on each side of the wall.
- b. Where roof-ceiling framing elements are perpendicular to the wall, the entire span of such framing and elements supporting

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such framing shall be of not less than 1-hour fire-resistive construction.

- c. Openings in the roof shall not be located within 5 feet of the area separation wall.

3. Two-hour area separation walls may terminate at roofs of entirely noncombustible construction.

4. Parapets of area separation walls shall have noncombustible faces including counterflashing and coping materials.

5. Where an area separation wall separates portions of a building having different heights, such wall may terminate at a point 30 inches above the lower roof level, provided the exterior wall for a height of 10 feet above the lower roof is of 1-hour fire-resistive construction with openings protected by assemblies having a .75-hour fire-protection rating.

EXCEPTION: The area separation wall may terminate at the underside of the roof sheathing, deck or slab of the lower roof, provided:

- a. Where the roof-ceiling framing elements are parallel to the wall, such framing and elements supporting such framing shall be of not less than 1-hour fire-resistive construction for a width of 10 feet along the wall at the lower roof.

- b. Where the lower roof-ceiling framing elements are perpendicular to the wall, the entire span of such framing and elements supporting such framing shall be of not less than 1-hour fire-resistive construction.

- c. Openings in the lower roof shall not be located within 10 feet of the area separation wall.

See Chapters 6 to 12 [in UBC] inclusive for special occupancy provisions.

Allowable area increases

Section 506. (a) General. The floor areas specified in Section 505 may be increased by one of the following:

1. Separation on two sides. Where public space, streets or yards more than 20 feet in width extend along and adjoin two sides of the building, floor areas may be increased at a rate of 1-1/4 percent for each foot by which the minimum width exceeds 20 feet, but the increase shall not exceed 50 percent.
2. Separation on three sides. Where public space, streets or yards more than 20 feet in width extend along and adjoin three sides of the building, floor areas may be increased at a rate of 2 1/2 percent for each foot by which the minimum width exceeds 20 feet,

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but the increase shall not exceed 100 percent.

3. Separation on all sides. Where public space, streets or yards more than 20 feet in width extend on all sides of a building and adjoin the entire perimeter, floor areas may be increased at a rate of 5 percent for each foot by which the minimum width exceeds 20 feet. Such increases shall not exceed 100 percent, except for buildings not exceeding two stories in height of Group B, Division 4 Occupancy and one-story buildings housing aircraft storage hangars and as further limited in Section 902 (b) for aircraft repair hangars.

(b) Unlimited area. The area of any one- or two-story building of Group B and Group H, Division 5 Occupancies shall not be limited, if the building is provided with an approved automatic sprinkler system throughout, as specified in Chapter 38 [in UBC], and entirely surrounded and adjoined by public space, streets or yards not less than 60 feet in width. The area of a Group B, Division 4 Occupancy in a one-story Type II, Type III 1-hour or Type IV building shall not be limited if the building is entirely surrounded and adjoined by public space, streets or yards not less than 60 feet in width.

(c) Automatic sprinkler systems. The areas specified in Table 5-C [in UBC] and Section 505 (b) may be tripled in one-story buildings and doubled in buildings of more than one story if the building is provided with an approved automatic sprinkler system throughout. The area increases permitted in this subsection may be compounded with that specified in paragraphs 1, 2 or 3 of Subsection (a) or this section. The increases permitted in this subsection shall not apply when automatic sprinkler systems are installed under the following provisions:

1. Section 507 for an increase in allowable number of stories.
2. Section 3802 (f) for Group H, Divisions 1 and 2 Occupancies.
3. Substitution for 1-hour fire-resistive construction pursuant to Section 508.
4. Section 1715, Atriums.

Maximum height of buildings and increases

Section 507. The maximum height and number of stories of every building shall be dependent upon the character of the occupancy and the type of construction and shall not exceed the limits set forth in Table 5-D [in UBC], except as provided in this section and as specified in Section 503 (a) for mixed occupancy buildings.

The story limits set forth in Table 5-D [of UBC] may be increased

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by one story if the building is provided with an approved automatic sprinkler system throughout. The increase in the number of stories for automatic sprinkler systems shall not apply when the automatic sprinkler systems throughout are installed under the following provisions:

1. Section 3802 (f) for Group H, Divisions 1 and 2 Occupancies
2. Section 506, for an increase in allowable area.
3. Substitution for 1-hour fire-resistive construction pursuant to Section 508.

EXCEPTIONS:

1. Towers, spires and steeples erected as a part of a building and not used for habitation or storage are limited as to height only by structural design if completely of noncombustible materials, or may extend not to exceed 20 feet above the height limit in Table 5-D [in UBC] if of combustible materials.

2. The height of one-story aircraft hangars shall not be limited if the building is provided with automatic sprinkler systems throughout as specified in Chapter 38 and is entirely surrounded by public space, streets or yards not less in width than one and one-half times the height of the building.

4. Section 1715, Atriums.

See Chapters 6 to 12 inclusive [in UBC] for special occupancy provisions.

Fire-resistive substitution

Sec. 508. Where 1-hour fire-resistive construction throughout is required by this code, an approved automatic sprinkler system, as specified in Chapter 48 [UBC], may be substituted, provided such system is not otherwise required throughout the building.

EXCEPTION: Such substitution shall not waive or reduce required fire-resistive construction for:

1. Occupancy separations [Section 503(c)].
2. Exterior wall protection due to proximity of property lines [Section 504 (b)].
3. Area separations [Section 505 (e)].
4. Shaft enclosures [Section 1706].
5. Corridors [Section 3305(g) and (h)].
6. Stair enclosures [Section 3309].
7. Exit passageways [Section 3312(a)].
8. Type of construction separation [Section 1701].
9. Atriums constructed in accordance with Section 1715.

Enclosures for stairways, elevators, ducts, and chases shall be in

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accordance with the following:

1. DOD 4270.1-M Dod Construction Criteria Manual, Enclosures.
2. NFPA No. 80 Fire Doors and Windows.
3. NFPA No. 90A Standard for the Installation of Air-Conditioning and Ventilating Systems.
4. NFPA No. 90B Standard for the Installation of Warm Air Heating and Air-Conditioning Systems.
5. NFPA No. 91 Standard for the Installation of Blower and Exhaust Systems for Dust, Stack and Vapor Removal or Conveying.
6. NFPA No. 101 Life Safety Code.
7. NFPA No. 211 Standard for Chimneys, Fireplaces, and Vents.
8. NFPA No. 220 Building Construction, Standard Types.

Electronic equipment vans may require grouping for functional reasons. Vans equipped with automatic extinguishing systems can be grouped together to form total areas of 5000 square feet. Arrangements of vans shall permit direct access to each van for fire-fighting. Grouping of unprotected vans shall not exceed 2000 square feet. A minimum separation of 15 feet shall be provided between all van groups.

guidance FIRE PROTECTION/3 Recommended Materials**b. Hazard of contents classifications**

The hazard of contents of any structure shall be classified as low, ordinary, or high in accordance with the following:

- Low-hazard contents shall be classified as those of such low combustibility that no self-propagating fire can occur and that, consequently, the only probable danger requiring emergency exits will be from panic, fumes, smoke, or fire from some external source.
- Ordinary hazard contents shall be classified as those liable to burn with moderate rapidity or to give off a considerable volume of smoke, but from which neither poisonous fumes nor explosions are to be feared in case of fire.
- High-hazard contents shall be classified as those liable to burn with extreme rapidity or from which poisonous fumes or explosions are to be feared in the event of fire.

3. a. Fire protection of constructed elements

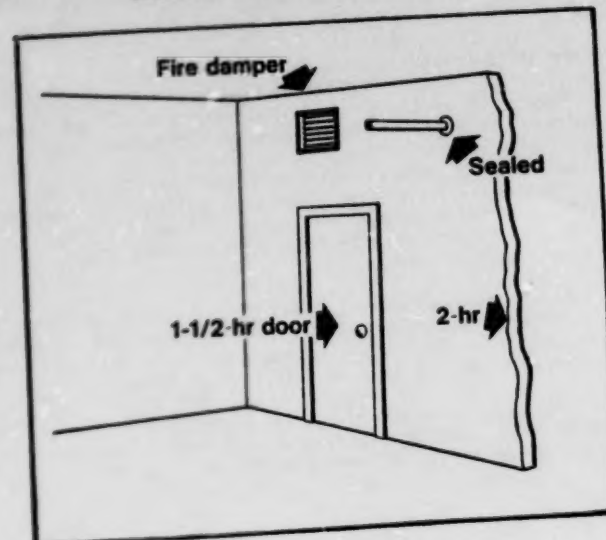
See Tables 7 and 8 under Policy/SOP for fire protection of constructed elements.

b. Fire-rated walls (including doors/dampers) (137) 8-2-8

Fire resistance ratings for fire walls and partitions depend on building occupancy. Fire walls shall be parapeted through combustible, limited combustible, and metal deck roofs. Fire stops shall be provided where cables, conduit, telephone wire, or ducts penetrate fire walls. The fire resistance ratings shall be maintained in the choice of material for fire stops. Manufactured devices are available for horizontal or vertical fire stops that will accommodate many cables of different sizes. They are watertight as well as fire-resistant. Other acceptable fire stops can be made, for example, by stuffing the openings around the cables with a mineral fiber then spraying it with an approved flame-retardant coating. Draft stops of gypsum board on wood or metal frame are required in combustible suspended ceiling spaces to divide those spaces into areas not exceeding 3000 square feet (280 square meters). Self-closing, latching access doors of similar construction shall be provided in the draft stop where there is no other access to an area.

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OPENINGS IN FIRE BARRIERS



FIRE BARRIER

OPENING PROTECTIVE

2-hour	→	1 1/2-hour rating
1-hour	→	1-hour rating
(Note exceptions)		
3/4-hour	}	20-minute rating
1/2-hour		
20-minute		

Ductwork: NFPA 90A

Door, Window Assemblies: NFPA 80

FIRE BARRIER TESTS

Floor-ceiling Assemblies: NFPA 251

Doors: NFPA 252

Windows: NFPA 257

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Protection of openings--Although blank, unpierced firewalls are preferable, door openings shall be provided when necessary, in accordance with NFPA No. 80. Fire doors are required on each side of the door opening in 4-hour fire walls. All fire doors shall be listed by Underwriters' Laboratories, Inc., or approved by Factory Mutual's Laboratories. Local fabrication of fire doors shall not be permitted. Protection of conveyor openings through fire walls shall be in accordance with NFPA NO. 80. The duct openings are to be protected in accordance with NFPA No. 90A, Air-Conditioning and Ventilating Systems.

C. Interior finishes

The interior finish shall conform to NFPA 101 as follows:

1. Interior finish for all exits and sleeping rooms shall be Class A only. Interior finish for all other areas shall be either Class A or B.
2. Class C, D, and E materials are not permitted.
3. Smoke ratings developed by Standard Test Method for Surface Burning Characteristics of Building Materials, ASTM E-84, shall not exceed 50 for Class A materials and 100 for Class B materials.
4. Cellular plastics shall not be used as interior finish materials.

Existing construction--In the case of combustible interior finishes in existing buildings, alternative measures to provide the necessary safeguards are--

1. Cover combustible surfaces with gypsum board or other materials meeting the requirements of paragraphs 1 through 4 above.
2. Protect the building with properly designed automatic sprinkler systems.

Carpet systems (carpeting and underlay combined)

1. Basic flammability requirements. Federal law requires that all carpet manufactured for sale shall comply with the Department of Commerce Standard for the Surface Flammability of Carpets and Rugs. DOC FF 1-7 (pill test).
2. Corridors. Carpet systems for corridors shall meet specific acceptance criteria when tested in accordance

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with Federal Test Method Standard 372 or Underwriters' Laboratories Chamber Test, UL 992. For this purpose, a corridor is defined as an enclosed space connecting a room or compartment with an exit and includes normal extensions such as lobbies and other enlarged areas. The flame propagation index of less than 4.0 as determined by UL Chamber Test, UL 992, is acceptable for corridor systems in all facilities. The minimum acceptance criteria (average critical radiant flux) as determined by Federal Test Method Standard 372 for corridor carpet systems shall be 0.25 watts per square centimeter.

Insulation--Thermal and acoustical insulation shall have flame spread rating no higher than 75 and smoke rating no higher than 150 by the Standard Test Method for Surface Burning Characteristics of Building Materials, ASTM E-84. Cellular plastic insulation shall be tested in the same densities and thicknesses as the material that will be used in construction.

EXCEPTION: For certain types of installations, ratings are increased or not required as follows:

- a. Flame spread 100--no smoke limitation--Compliance with the smoke developed limitation is not required and a greater flame spread rating of 100 is permitted for insulation, including insulating sheathing, installed inside wall assemblies. In such installations, the interior finish materials shall conform to requirements for Interior Finishes and shall have a minimum fire retardant rating of 15 minutes by Standard Methods of Fire Tests of Building Construction and Materials, ASTM E-119, when tested as it will be installed in actual construction.
- b. No flame spread or smoke limitation--Compliance with flame spread and smoke developed limitation is not required for the following applications:
 1. Insulation installed above poured-concrete or poured-gypsum roof decks, nominal 2-inch (50-mm) thick tongue-and-groove wood-plank roof decks, or precast roof-deck panels or planks approved by Factory Mutual as noncombustible.
 2. Insulation installed above roof decks for which the entire roof construction assembly, including insulation, is Underwriters' Laboratories listed as Fire-Classified or Factory Mutual approved for Class I roof deck construction.

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3. Insulation contained entirely inside panels for which the entire panel assembly, as will be used in actual construction, meets the flame spread and smoke developed limitations cited before.
4. Insulation isolated from interior of building by masonry walls, masonry cavity walls, insulation incased in masonry cores, or concrete floors.
5. Insulation installed over concrete floor slab and completely covered by wood tongue-and-groove flooring without creating air spaces in the flooring system.
6. Insulation completely enclosed in hollow metal doors.
7. Insulation installed between new exterior siding materials and existing exterior siding of wood board, plywood, fiberboard, or gypsum exterior wall sheathing.

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4. a. Fire detection systems

1. Automatic fire detection systems

Automatic system actuators shall be installed in structures with high dollar value, strategic value, and specific enumeration in DOD Construction Manual 4270.1-M. In addition to the specific locations recommended for each type of device, reference should be made to the listing of approval agency (UL or FM) recommendations for locating the particular fire detector. (187) 8-5

The system provides the automatic detection of fire throughout designated areas, buildings, structures, or equipment. The system shall activate an audible evacuation alarm and transmit a coded alarm signal to the fire alarm communication center. The item consists of necessary automatic detection devices, circuits or tubing, connected circuitry, control panels, signal indicator, trouble signals, test devices, power supply, emergency power supply, alarm transmitter, supplemental manual boxes and other features. (138) 13.19

- a. Unless automatic suppression systems are required, complete automatic fire detection systems and fire extinguishers constitute the minimum level of acceptable fire protection for all new construction. Smoke detectors in return air plenums do not meet this minimum level.
- b. Areas protected with automatic fire detection systems will include occupied spaces, unoccupied spaces, and attics.
- c. When a system is divided into two or more zones, a graphic annunciator constructed of engraved phenolics or metals shall be installed at a location determined by the local fire department.
- d. Battery-powered smoke detectors are not approved for use. (138) 13.19

Heat-activated devices

Two main types of heat-actuated devices are used as fire detectors: (1) the fixed-temperature type, designed to operate when the temperature reaches a predetermined value; and (2) the rate-of-rise type, designed to operate when the rapidity of temperature rise exceeds a predetermined rate (usually 15° to 20°F per minute) regardless of the temperature level. Some devices combine these two characteristics so that a fixed-temperature device operates in case the temperature rises too slowly to operate the rate-of-rise device. (136) 8-6

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The maximum spacing for satisfactory operation depends on the device's sensitivity, the ceiling construction, and the occupancy. For flat, smooth ceilings, the maximum satisfactory spacing between devices varies from 12-1/2 to 30 feet, depending on the particular device. The distance from a detector to the nearest wall or partition shall be one-half the distance between detectors. Closer spacing may be needed because of the type of construction in the protected area, possible drafts, heating systems, and other factors. For open-joisted ceilings, the spacing measured at right angles to the solid joists should not exceed 50 percent of the detector's smooth-ceiling spacing. (136) 8-6

Products of combustion devices

Smoke-actuated devices are especially applicable to ducts of air-conditioning and ventilating systems, electronic computer system installations, record vaults, and other areas of high value. Smoke-actuated detectors operate on a photoelectric principle or involve radioactive ionization. (136) 8-6

Spot-type smoke detectors on smooth ceilings with no air flow in the occupancy can be placed on 30-foot spacings or in such a way that they will cover 900 square feet. In rooms that have dominant air flow (for example, 20 air changes per hour) a maximum coverage of approximately 200 square feet per detector shall be used. Beam-type smoke detectors on smooth ceilings and with no forced air flow present can provide acceptable detection with the associated light beam for such equipment spaced up to 30 feet from the detector head. (136) 3-6

Smoke detection systems shall be provided in electronic equipment areas, record and tape storage rooms, and other rooms that exit through the electronic equipment area. The detector shall transmit a signal to the fire department. (138) 13-31

Smoke detection systems shall be provided in raised floor spaces containing exposed nonmetallic sheathed cables. Fixed-temperature, rate-compensated or fixed temperature, rate-of-rise heat detectors may be provided in raised floor spaces when smoke detectors would not be effective. Systems shall transmit a signal to the fire department. (138) 13-31

Smoke detectors can be used to monitor air-conditioning and ventilation systems and to supervise the control of fans and ventilation dampers. It should be noted that smoke detectors designed for room protection cannot be used for these special purposes. (136) 8-7

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Smoke detectors should be used in any occupancy for which slowly developing, smoldering fires are likely to occur and for which personnel life safety is the primary consideration. (137) 8-9-3

b. Fire detection and notification systems

These systems shall be designed in accordance with the requirements of, but not limited to: NFPA 70 National Electrical Code, Standard for the Installation, Maintenance and Use of Central Station Signaling Systems, NFPA 71; Standard for the Installation, Maintenance and Use of Local Protective Signaling Systems for Watchman, Fire Alarm and Signaling Service, NFPA 72A; Standard for the Installation, Maintenance and Use of Auxiliary Protection Signaling Systems for Fire Alarm Service, NFPA 72B; Standard for the Installation, Maintenance and Use of Remote Station Protection Signaling Systems, NFPA 72C; Standard for the Installation, Maintenance and Use of Proprietary Protective Signaling Systems for Guard, Fire Alarm and Supervisory Service, NFPA 72D; Standard for Automatic Fire Detectors, NFPA 72E; Household Fire Warning Equipment, NFPA 74; and Public Fire Service Communications, NFPA 1221. (138) 13.19

Fire alarm systems shall provide the following basic features, depending on the alarm type required: (187) 8-1

1. Transmission of signals to fire department alarm center and other central locations, as required, by telegraphic, supervised telephonic, or radio techniques
2. Permanent record of alarm signal, time, and date, (desirable but not mandatory)
3. Automatic supervision of box and alarm circuits
4. Automatic conditioning for transmission of signals under line fault conditions of single ground, single open, or both
5. Automatic testing of radio signaling devices
6. Sealed plug-in relays in control panels
7. Location lights at all exterior signal initiating devices
8. Any special requirements specified in AR 420-90.

Fire alarm systems are classified as follows: (187) 8-1

Proprietary systems--Those in which the central station office is located within the property being protected. The systems are owned or leased by the protected property owner and operated entirely under that person's control. Details associated with this system are found in NFPA No. 72D, Proprietary Protective Signaling Systems.

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Auxiliary protection systems--Those protecting an individual building or group of buildings and using municipal fire alarm facilities to transmit a signal to the fire department. NFPA No. 72B, Auxiliary Protective Signaling Systems, provides requirements for this type of system.

Remote-station systems--Those using a direct-circuit connection between signal-initiating devices at the protected property and signal-receiving equipment in a remote place such as a public fire station. These systems usually consist of a supervised local system connected by a leased, supervised telephone circuit to a constantly attended public fire station or other constantly attended remote station. This class of protective system is as effective as the auxiliary local current system and shall be used when cost estimates and reliability justify. Remote station systems shall comply with NFPA No. 72C, Remote Protective Signaling Systems.

Central station systems--One or more signaling systems in which several signals are transmitted to a central equipment station. Facilities central station protection services shall insure that the system complies with NFPA No. 71, Central Station Protection Signaling Systems.

Local protective systems--Those producing an alarm or supervisory signal only on the premises being protected. This system is not recommended for Army requirements, but may be required when alarm signal cannot be transmitted to a fire station. Under such circumstances, a qualified operator must be present at the annunciator at all times. When used, such systems shall comply with the requirements of NFPA No. 72A, Local Protective Systems.

The alarm system chosen shall, whenever possible, be directly connected to a fire station so trained firefighting personnel can respond as rapidly as possible. Thus, auxiliary protection systems and remote station systems shall be considered in all cases for signal transmission. (187) 8-3

Details on wiring, specific circuits, power supplies, and other details of the specific alarm systems can be found in the appropriate NFPA alarm standard as summarized in the following table. In addition to requirements in these standards, all electrical requirements shall comply with National Electrical Code NFPA No. 70 or Corps of Engineers requirements, whichever is more stringent. (187) 8-3

2. Manual alarms

Watchman or guard supervisory key stations for central station, proprietary, and local protective systems--Key stations shall be provided at critical locations compatible with reasonable reporting times and routes. Key station equipment shall be listed or approved by a recognized fire testing laboratory. (187) 8-3

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Table 12 SUMMARY OF SIGNAL FUNCTIONS AND PROTECTIVE SYSTEMS (187) 8-2		
NPFA No.	Signal Functions	Type of Protective System
71	Guard, fire alarm and supervisory service	Central station
72A	Watchman, fire alarm and supervisory service	Local
72B	Fire alarm	Auxiliary
72C	Fire alarm and supervisory service	Remote
72D	Watchman, fire alarm and supervisory service	Proprietary
72E	Automatic fire detectors	
An exterior manual fire alarm system should be used when required. The system is for fire and other emergencies reporting and may use either voice or coded signal. It may be part of the base internal wire and telephone system or may be radio-operated. It includes initiating signal boxes, circuits, central station receiving equipment, cabinets and consoles, antennas, and power supply equipment. Fire reporting facilities will not be provided at small, isolated areas, ammunition and ordnance storage, and similar restricted areas where personnel are not usually present to detect fires. They also are not provided at housing, recreational, administrative, support, and other nonhazardous areas where there are adequate administrative, public, or private phones. (138) 13-20. Fire reporting stations are required within 30 feet of bulk fueling systems and operating storage, pumphouses, meter pits, fill stands, and hydrant fueling points, but not closer than 150 feet to fueling hydrants, fill stands, and similar loading or unloading points. (138) 13-20 Fire reporting telephones will connect, normally over separate circuits, to central fire reporting switchboards. Wireless fire reporting transmitters shall be coded. (138) 13-20 Posts for mounting fire-reporting instruments at aircraft parking, fueling, and maintenance aprons shall not exceed more than 24 inches above finished grades. The ruby identification light and instrument on these posts shall not rise above the top of the post. (138) 13-20 Manual fire and evacuation alarm systems shall be installed in: (136) 13-4 • Barracks, dormitories, OQs, and similar sleeping quarters		

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• Military prisoner confinement buildings not otherwise provided with automatic sprinkler or automatic fire detection systems • All facilities with occupants such as administration buildings, clubs, schools, classrooms, hospitals, laboratories, industrial plants, and similar structures in accordance with NFPA No. 101 (reference 131). • Military hospitals using supervised coded systems. Exterior fire reporting facilities shall be intalled in occupied areas to provide for manual reporting of fires. Telegraphs, radios, or supervised telephones should be provided in built-up areas at military installations. The type of system chosen shall be established on the basis of dependability, initial cost, and life cycle costs to maintain the system in operational condition. Extensions of fire reporting systems will require consideration of compatibility with existing equipment. Exterior fire reporting facilities shall not be provided at small, isolated areas, ammunition and ordnance storage, and similar restricted areas where personnel are not generally present. (136) 13-4 Manual fire-alarm boxes--These boxes shall be provided in the first story and one in each alternate story where floor areas are less than 10,000 square feet. At least one box shall be provided on every floor where the largest fire area is 10,000 square feet or more. Additional boxes are also needed on each floor if the horizontal travel distance to the nearest box would otherwise be more than 200 feet. One or more manual fire-alarm boxes shall be installed on each automatic fire-alarm system, one at the top and one at the bottom of each stairway and at each building exit. In addition to these requirements, DOD Construction Criteria Manual 4270-1.M shall be consulted for guidance in locating manual actuating devices. (187) 8-4 Uncoded manual fire alarm stations--These can be used on small, local fire-alarm systems and on auxiliary and remote-station systems for transmitting alarms from the protected property, such as motor pools, radar installations, guard facilities, and small medical facilities with a surface area of 15,000 square feet or less, to remote locations, such as a public fire station or headquarters. Manual fire alarm boxes shall be mounted securely on the wall no less than 4-1/2 feet and no more than 6 feet above floor level. Additional requirements covering this topic are in Article 300 of the NFPA Standards. (187) 8-4 Code ringing boxes--Such devices indicate the location of a fire. They shall be used at properties with high dollar, strategic value and with 50 or more occupants. (187) 8-4 The following code ringing, manual fire-alarm boxes are available: 1. The plain interfering type, which may have several boxes

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connected on one circuit. Interference between alarm signals from two boxes, actuated simultaneously, can occur with such systems, which results in the possibility of not being able to identify the location of either fire source.

2. Partially noninterfering shunt systems partially or completely suppress the second alarm signal until the first alarm has been completely recorded, thus positively identifying one fire location.
3. Positive noninterfering code ringing boxes permit both alarms to be transmitted for positive fire location. Such systems do not lose the alarms, although one signal may have slightly delayed transmission.

Noninterfering or partially noninterfering boxes are not required in small, local systems, especially when all boxes on a circuit are in a single building of moderate size. Partially noninterfering boxes are advised for large, local systems and for proprietary systems of moderate size. Positive, noninterfering, and succession boxes are expensive and are used mainly in municipal fire-alarm and large proprietary systems. Combination fire-alarm and watchman's signaling boxes are also available for use on fire-alarm systems. These combined boxes can transmit fire alarms or watch-station signals, as desired. (187) 8-4

Combined watch reporting and fire-alarm systems--These systems shall be of a coded type in accordance with requirements for fire alarms and watchman's tour supervisory service in NFPA 72D. Equipment used shall be approved by a suitable nationally recognized commercial or U.S. Government testing laboratory. (187) 8-5

3. Automatic alarms

Automatic fire alarm reporting and receiving system--This system receives coded fire, emergency, trouble, tamper, and system restore signals from detection/alarm and suppression systems. The system is generally located in the fire alarm or communication center and receives signals from the base internal wire and telephone system, radio transmissions, or both. (138) 13-20

Waterflow alarms--Alarms that respond to the water flow in a sprinkler system are mandatory wherever a sprinkler system is installed and shall comply with the sprinkler system water flow alarm and supervisory signal service articles of the NFPA Standards. One exterior, local, low-air-pressure alarm of the electric gong type shall be provided at each dry-pipe valve house to be actuated by a pressure switch. The electric circuits for the local water flow alarm and local low-pressure alarm can use the same exterior gong. An exterior, local, noncoded waterflow alarm of an approved design shall be provided for each underground supply connection. This is to operate continuously until manual clearing. (187) 8-5

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See also "Detection systems."

4. Signaling devices

Alarm-sounding devices include bells, gongs, sirens, and horns. One or more approved systems that warn building occupants of a fire should be installed on each floor or area, located so that they can be heard plainly throughout the area and above the noise of machinery. In the case of hospitals, coded audible signals can be used in all nonpatient rooms, whereas coded visual signals can be used in patient rooms. Sounding devices of a fire-alarm system shall be distinctive from others in the same area. In closed-circuit supervised systems, the circuits for the alarm-sounding devices shall also be supervised. An exception can be made when approximately half the sounding devices are connected to each of two circuits equally distributed throughout the premises. Trouble-sounding devices shall give a signal distinctive from alarm-sounding devices. A switch for silencing the trouble-sounding device shall not be provided unless the silencing operation automatically transfers the trouble signal to a trouble light or visible indicator adjacent to the switch. (187) 8-7

5. Municipal fire-alarm systems

A municipal fire-alarm system is an electrically operated way to receive an emergency alarm and dispatch signals to fire companies whose responsibility is to respond to the reported emergency. This type of system includes provision for receipt of an emergency alarm by other means of transmission such as radio or telephone. The following two types of municipal fire alarm systems are recognized: (187) 8-7

Type A is a system in which a signal from a municipal fire-alarm box requires an operator to receive, check, and retransmit to responding personnel. This system is required for any area in which the number of emergency calls exceeds 1500 per year.

Type B is a system in which an alarm from a municipal fire-alarm box is automatically transmitted to responding personnel.

Fire-alarm boxes--When a municipal alarm box is located inside a building, it shall be as near as practical to the entrance. Any interior wiring associated with such boxes shall be installed in conduit or electrical metallic tubing in accordance with National Electric Code NFPA No. 70.

Location, type, and mounting--Exterior boxes shall be mounted securely on poles or pedestals and shall be equipped with an overhead, highly visible indicating light. Signaling devices in the boxes shall be driven mechanically or electrically and shall have noninterfering, successive operation. In addition to providing street boxes for adequate protection, alarm boxes shall be installed at the main entrances of schools, hospitals, nursing homes, theaters, chapels and other places

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of public assembly.

Power supplies--The conductors of a fire alarm system power supply shall be connected to the line side on the main service of a commercial light or power supply circuit. In buildings housing fire alarm equipment, power may be obtained from the load side of the main disconnect switch. A reliable secondary source of power shall also be connected to such circuits. These sources may be battery- or engine-driven generators. Engine-driven generators shall comply with the requirements of NFPA No. 37, Standard for Stationary Combustion Engines and Gas Turbines.

Cables--Cables used for inside and outside wiring associated with municipal fire alarm systems shall have adequate dielectric and mechanical strength for the intended purpose. Further details for the proper selection of inside and outside cables can be found in The National Electric Code, NFPA No. 70, and Municipal Fire Alarm Systems, NFPA No. 73.

Telephone facilities--Since many alarms are given over commercial telephone lines, a specific telephone(s) shall be provided for this purpose only at the fire department communication center.

C. Suppression systems

The following systems are installed in compliance with functional requirements in the following standards: Standard for the Installation of Carbon Dioxide Extinguishing Systems, NFPA 12; Standard for the Installation of Halon 1301 Extinguishing Systems, NFPA 12A; Standard for the Installation of Halon 1211 Extinguishing Systems, NFPA 12B; Standard for the Installation of Sprinkler Systems, NFPA 13; Standard for the Installation of Foam Extinguishing Systems, NFPA 11; Standard for the Installation of Synthetic and Combined Agent Foam Systems, NFPA 11B; Standard for the Installation of High Expansion Foam Systems, NFPA 11A; Standard for the Installation of Foam-Water Sprinkler and Spray Systems, NFPA 16; Standard for the Installation of Standard Pipe and Hose Systems, NFPA 14; and the Standard for the Installation of Dry Chemical Extinguishing Systems, NFPA 17. (138) 13-20

1. Automatic systems

The following requirements apply to all major electronic installations of high monetary value essential to operation of weapons and communication systems, whether Government-owned or leased, including EDP computers, avionics, communications, and major electronic training devices (aircraft simulators included). (138) 13.31

Equipment incidental to the facility or area operation will not be given special protection, but will be protected in the same way as the overall area. This includes, but is not limited to, word processing stations, typewriters, desktop computers, individual data output equipment, telephones,

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building telephone switching systems, field interface units and reproduction equipment.

New construction--Facilities to house electronic equipment shall be Type I or Type II construction and separated from other occupancies by fire-rated walls or partitions. Additional guidance for construction and protection is in NFPA 75, Computer/Data Processing Equipment, and AFM 88-4.

Automatic sprinkler systems. Shall be provided in facilities or areas thereof to insure the maximum degree of life safety or property protection when the size, type of construction, occupancy, or other conditions create high monetary or severe strategic fire loss potential. This protection also shall be provided when the probability of fire severity is beyond local firefighting control or water supply. (138) 13-20

Standard wet-pipe or preaction automatic sprinkler systems shall be provided in the following areas. (138) 13.31

- Electronic equipment areas with combustible construction materials or where combustible materials are processed or stored including cards, paper, and plastics, but excluding cards, paper, disks, and tapes inside machines.
- Areas containing major electronic training devices with combustible materials in the basic structure or as part of the simulator trainer.
- Combustible record storage rooms.
- Areas adjacent to the electronic equipment space. When economically advantageous, fire cutoffs with fire-resistant ratings equal to the rating provided for structural elements of the building can be provided in buildings of fire-resistive construction instead of sprinklers.
- Automatic power shutoff shall be connected to the detection system. This can be through an automatic memory safe cycle not to exceed 60 seconds. (138) 13.31.

The automatic sprinkler system must be installed in compliance with the functional requirements criteria established in NFPA 13, Standard for the Installation of Sprinkler Systems. (138) 13-20

Gaseous extinguishing systems. Halon 1301 fire suppression systems can be installed in sprinklered or unsprinklered electronic equipment areas in which important military missions are conducted and continued operation is essential to the on-going mission (for example, combat control centers, weapon control systems, critical communications facilities). These systems can also be provided for base-

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level ADPE business systems (for example, inventory control, data services) whose loss would impair administrative or other nonessential functions and would result in an economic loss but would not critically affect overall mission. MACOMs will establish the individual system's relative importance with respect to mission accomplishment and continuity. Depending on the project, this action may be coordinated with AF Communications Command and the responsible system project office (SPO) such as those under Electronics Systems and Aeronautical Systems Divisions. (138) 13-32

Halon 1301 shall be provided for raised floor spaces containing nonmetallic, heated, exposed cable. In electronic equipment installations that have an equipment replacement value of less than \$500,000 and in raised floor areas less than 2000 cubic feet (57 cubic meters) in volume, fixed automatic extinguishing systems can be omitted from the raised floor spaces.

System activation shall be by either cross zones or matrix detection. Activation of any single detector shall transmit a signal to the fire department and provide local audible or visual notification. Pick-up by two or more detectors shall activate the Halon system, sound an audible or visual evacuation alarm, and transmit a signal to the fire department.

A system abort may be provided, but must be a type that requires positive pressure on the switch until the system is reset.

In Type I or II structures (or a Type I or II addition to an existing structure), a Halon 1301 total flooding fire suppression system can be installed to protect electronic equipment.

These systems are authorized in:

- Room(s) containing the electronic equipment
- Any room with direct access to Halon-protected ADPE room(s) when the only exit from the room is through the Halon-protected room.
- Air plenums above or below the Halon-protected area.
- Space above or below the Halon-protected room, if the space or room contains combustibles; contains an opening to the Halon-protected area totaling more than 100 square inches; or contains electric cables not enclosed in conduit
- Supply room or tape library

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- Room(s) adjacent to a Halon-protected area and housing high-value equipment that can be economically protected, considering the fire risks involved, with an extension of the Halon 1301 system.

Note: If the room has an opening into the Halon-protected area, as a minimum, it must have a smoke detector(s) for alarm only. The space above the suspended ceiling in an electronic equipment area can be protected with smoke detectors; however, it must have Halon protection if it is used as an air plenum or contains combustibles unless the ceiling system is 1-hour fire rated.

If the area is protected with Halon 1301, it must have a forced ventilation exhaust system to the outside of the facility for smoke and Halon removal.

Sprinkler and Halon systems are not normally installed in the same areas.

Halon 1301. This is a colorless, odorless, electrically nonconductive gas that extinguishes fires by inhibiting the chemical reaction of fuel and oxygen. Persons can be exposed to Halon 1301 vapors in low concentrations for brief periods without serious risk. However, exposure to high concentrations for prolonged periods may produce dizziness, impaired coordination and disturbances in cardiac rhythm. Therefore, prompt evacuation of the premises is recommended.

The Halon 1301 system has the following characteristics:

- Automatic total flooding capability is supplied for each area above.
- The system should be "zoned" with each area designated a specific zone. This is so Halon coverage is only applied to the zone requiring it.
- The system should be able to totally flood a zone with Halon in approximately 60 seconds.
- The Halon concentration applied to any zone should not exceed 5 percent design concentration by volume. The Halon weight requirements will be established based on mathematical formulas that consider the volume of the zone (area) to be covered and the specific volume of the superheated Halon 1301 vapor in accordance with NFPA, Volume 1, Chapter 12A.
- Several combustion product (smoke) detectors (at least two per zone) should be spaced throughout each zone interconnected with the Halon system to activate the Halon system in the following ways:

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1. If one detector activates in any one zone, TP and utility power to that zone should shut down automatically and an alarm will sound in the zone and at the base fire station. However, Halon protection should not be activated. Power will not be shut down in only certain rooms unless more than one detector activates.
2. If more than one detector activates in any one zone, power to that zone will shut down, an alarm will sound, Halon activation should begin, and an alarm will sound at the base fire station.
 - The system should have an uninterruptible power source in accordance with the NFPA.
 - The Halon system should have a complete reserve supply manifolded into the system with a normally closed valve.
 - The system should be able to be shut down manually to prevent damage or activation in the event of system malfunction or when it is apparent that the fire hazard condition does not require suppression by total flooding Halon.
 - All components used in this system should carry an Underwriter's Laboratory (UL) listing or equal approved use for fire protection.
 - The system should be designed, built, and tested in accordance with the NFPA.
 - The system design should include adequate provision for venting the zones covered by Halon to relieve the pressure buildup from releasing large quantities of Halon 1301. Venting design should be in accordance with the NFPA.
 - Bilingual signs should be placed at all entrance doors to areas covered by Halon advising that these areas have Halon systems.
 - Provide purge ventilation in the air-conditioning systems for areas protected by Halon systems. One complete air change in 10 minutes is recommended.
 - All other areas should be protected by an automatic sprinkler system conforming to NFPA 13, NFPA 20, and AFM 88-15.

Existing construction. ([138] 13-33) House essential electronic equipment in existing Type I or II structures according to paragraph 13.35b of reference 138. Type III, IV, or V structures shall require HQ USAF/LEEE approval. On approval, existing types III, IV, or V structures may be used, provided the building is completely protected by a properly

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installed and maintained automatic sprinkler system and the enclosure for the equipment complies with requirements of NFPA 75.

1. Extend the fire walls of Type III, IV, or V facilities through combustible exterior walls and roofs and construct wings, returns, and parapets. Extend parapets 3 feet above the roof and wings 3 feet from exterior walls. Returns along exterior walls must run 20 lineal feet without windows, doors, or other openings.
2. When converting an existing structure for use as an equipment enclosure, remove all nonstructural, combustible materials and finishes including those exposed by this removal. All new materials shall be noncombustible.
3. Before installing a raised floor, apply a noncombustible insulating material to combustible structural floors. Also, remove any nonstructural combustible flooring such as wood or combustible tile on a concrete slab.
4. The supply room, tape library, computer rooms, and all perimeter walls must be constructed with 1-hour minimum fire resistant walls and ceilings and with class B self-closing fire doors.
5. When converting an existing structure for use as an equipment enclosure, a combustion product (smoke) detection system shall be provided.
6. Sprinkler systems should be installed as follows:
 - In a Type III, IV, or V building, provide complete automatic sprinkler protection.
 - In a Type I or II building not protected with sprinklers, provide an automatic sprinkler supply in the tape library and supply rooms from the domestic water system.
 - When the life safety code or this section requires automatic sprinklers for the entire building, also provide a sprinkler system for electronic equipment areas, unless they are Halon-protected.
 - Floor drains must be provided in electronic equipment rooms where sprinklers are installed.
2. Manual extinguishing systems

Portable fire extinguisher cabinets--Wall recessed (when space permits), flush-mounted recessed, or semirecessed

guidance FIRE PROTECTION/4 Systems

extinguisher cabinets shall be provided for all new construction. Distribution is to be according to NFPA Standard No. 10. The type and size shall be approved by the local fire department. Normally, only water, water/AFFF, Halon 1211, dry chemical (ABC), or dry powder (D) will be permitted.

Windowless facilities or underground areas ([138] 13-40)
--These include, but are not limited to, facilities that are hardened, windowless, underground, and parts of facilities with the same properties.

Any building or story (including basement) of a building over 1500 square feet (140 square meters) is considered windowless by one of the following definitions:

- No exterior wall is provided with more than 20 square feet (2 square meters) of opening entirely above ground level in each 50 linear feet (15 meters) of wall. Openings shall have a minimum dimension of 30 inches (760 millimeters), and shall be readily accessible to the fire department for firefighting and rescue.
- Openings as described above are located only on one side of a story, and the opposite wall is more than 75 feet (23 meters) from the openings.

For new construction:

- Automatic fire detection shall be provided.
- Facilities with combustible contents or Type III, IV, or V construction shall have an automatic sprinkler system.
- Facilities occupied by 100 persons or more (under normal or contingency conditions) shall be protected throughout by an automatic sprinkler system.
- Emergency lighting shall be provided in all areas.
- Standpipe outlets are required and shall be installed according to NFPA 14.

For existing construction:

- Automatic detection systems are required in all areas.
- Emergency lighting is required in all areas.

3. Water supply systems (137) 8-7-5

Water demand for sprinklers--The water demand required for sprinklers shall be determined from the applicable tables in this chapter.

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The design densities indicated in the seventh table are minimum densities and each sprinkler in the design area shall discharge at least the flow rate required to produce the stipulated density.

The design areas shown in this table are hydraulically the most remote and shall include all sprinklers on both sides of the cross-main. The areas indicated are for wet-pipe systems. When dry-pipe systems are used, the areas shall be increased by 30 percent.

Water demand for hose streams--Hose streams are needed concurrently with sprinkler discharge to effect final extinguishment or to wet down adjacent structures. The hose stream demand for sprinklered occupancies shall be determined from the applicable table.

Total water demand for sprinklered occupancies--The total water demand is equal to the sum of the sprinkler system water demand and the hose stream demand. The total demand shall be available at the sprinkler system connection to the underground main and at the flow pressure necessary to produce the required sprinkler density over a given area of sprinkler operation.

Water demands for unsprinklered facilities--This water demand depends on the occupancy, construction, exposure, access to the building site, and the fire department response. Fires in unsprinklered facilities require more water than fires in similar sprinklered facilities because water spraying by hose streams is less efficient and begins later than sprinkling. The water demand range and fire duration for unsprinklered occupancies shall be determined by the table applying to this situation. The following factors affect these ranges and shall be used to determine the water flow demand:

- Response time by fire department
- Firefighting access
- Exposures
- Type of construction
- Building height
- Building floor area
- Conflagration potential.

The water demand for unsprinklered facilities shall be available at a flow pressure no less than 20 pounds per square inch (140 kilopascals).

Duration of water supplies--The fire protection water supply shall be able to furnish the necessary flow and pressure for the duration indicated in Figures 9 and 10. Duration of the water supplies for open-head sprinkler systems shall not exceed 45 minutes.

guidance FIRE PROTECTION/4 Systems

Quantities of water storage required--The requirement for fire protection water storage is based on the assumption that there will be only one fire at a time. The quantity of water storage required is therefore equal to the product of the fire protection water demand and the required duration. This quantity represents fire protection requirements only and must be available at all times. Storage for domestic, industrial, and other demands must be added to these requirements to determine the total amount of water storage necessary at a facility. If the public water system supplying a Naval activity is reliable, provides a minimum of two connections to the activity with each connection providing at least 50 percent of required capacity, has adequate capacity and pressure to meet the activity's water requirements, and has a continuous reserve storage capacity at least equal to the required fire protection water storage, no separate water storage facility will normally be required.

Reduction in storage capacity. In computing the fire protection storage requirement, a reduction in storage capacity is acceptable if an adequate replenishment source is available. Factors that must be evaluated include the make-up facility's reliability, its sustained flow capacity, method of operation (automatic or manual), and flow limitations imposed on the capacity of treatment operations.

Total storage capacity. The total storage requirement for an activity is based on the storage required to supply the peak fire flow demand plus 50 percent of the peak daily domestic consumption.

Replenishment of storage--The water storage must be self-replenishing. It shall reach required volume during normal consumption within 48 hours, and within 24 hours by curtailing normal consumption.

Primary water supplies--Primary water supplies shall consist of one or a combination of:

- Two connections to a public water system (one connection is ample for a small activity such as a Reserve Training Facility)
- Elevated tanks or reservoirs
- Multiple pumps with adequate suction.

Secondary water supplies. When the public water supply is inadequate or unreliable, a secondary supply is required. This secondary supply shall be gravity tank, pressure tank, booster pumps taking suction from an adequate capacity main, or fire pumps taking suction from an adequate source. Normally, ground level tanks and pumps provide the most economical supply. Elevated tanks generally require excessively high trestles to provide

guidance FIRE PROTECTION/4 Systems

enough pressure to satisfy large water flow demands. Pressure tanks are used for small, isolated facilities because of their limited capacities.

Design criteria--Water supplies shall be designed in accordance with NAVFAC DM-5, Civil Engineering.

Pump equipment--Pumps for fire protection shall have adequate capacity with reliable power and water supply. This equipment shall conform to requirements of NFPA No. 20, Centrifugal Fire Pumps, and NAVFAC DM-5, Civil Engineering. Fire pumps, prime movers, and all other equipment including automatic accessories shall be listed by Underwriters' Laboratories or approved by the Factory Mutual Engineering Corporation.

Prime movers--Diesel engines, electric motors, and steam turbines shall be installed in strict accordance with NFPA No. 20, Centrifugal Fire Pumps. Combustion engine drive shall be provided, unless electric power is provided from two separate sources. Two smaller pumps are more reliable than one large pump. All fire pumps shall be arranged for automatic starting and manual shutdown using Underwriters' Laboratories listed or Factory Mutual approved fire pump controllers.

Distribution mains--Underground mains in water supply systems shall be installed in accordance with the requirements of NFPA No. 24, Outside Protection, and NAVFAC DM-5. The distribution system shall be sized to accommodate fire flows plus domestic and industrial or flushing demands that cannot be restricted during fires. Distribution mains shall be looped to provide at least 50 percent flow in case of a single break.

Valves--Control valves shall be provided in each water supply source (such as at tanks and pumps). Enough sectional valves shall be provided so that no more than a total of five hydrants and sprinkler systems or no more than three sprinkler system shall be out of service due to a single break. Control valves shall be either postindicating or outside stem and yoke type. Sectional valves can be key-operated.

Drawings shall be provided showing all control and sectional valve locations, valve sizes, and number of turns. All left-hand valves shall be clearly indicated on drawings.

Left-hand valves shall be clearly labeled on curb box covers, valve wheels, and similar items.

Hydrants--Fire hydrants shall be Underwriter Laboratories listed or Factory Mutual approved and shall have two 2-1/2-inch (63.5 millimeter) hose outlets and one 4-inch (101.6-millimeter) or 4-1/2-inch (114.3 millimeter) suction connection with National Standard Fire Hose Threads in accordance with NFPA No. 24, Outside Protection, and NFPA No. 1953, Screw Threads and Gaskets for Fire Hose Connections.

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Wet-barrel or California-type hydrants are preferable in areas with no danger of freezing. If local municipal departments use nonstandard connections, adapters shall be made and supplied to engine companies that respond to station fires.

Painting and identification. Fire hydrants shall be painted in accordance with NAVFAC P-309, Color for Naval Shore Facilities, which requires yellow barrels and yellow tops for potable water and yellow barrels with red tops for nonpotable water. Each hydrant shall be numbered to correspond with the number on the station water distribution system.

Installation requirements. All hydrants shall be installed adjacent to paved areas no closer than 3 feet (1 meter) and no farther than 7 feet (2.1 meters) from the roadway shoulder or curb line at which they will be accessible to fire department apparatus. In general, hydrants shall be located at least 50 feet (15 meters) from the buildings they protect. Hydrants shall be installed with no less than a 6-inch (152-millimeter) connection to the supply main and shall be valved at the connection. Barrels shall be long enough to permit at least an 18-inch (457-millimeter) clearance between the bottom of the 4-1/2-inch (114.3 millimeter) pumper connection and grade. The ground shall be graded so that any surface drainage is away from the hydrant. Installation shall be in accordance with NFPA No. 24, Outside Protection.

Spacing requirements--Enough hydrants shall be provided so that the hose stream demand can be met with no more than 750 gallons per minute (50 liters per second) from any single hydrant. Hydrants shall also be spaced in accordance with the following requirements:

- All parts of buildings shall be reached by hose lays of not over 350 feet (110 meters) with consideration given to accessibility and obstructions.
- A minimum of two hydrants shall be provided within 500 feet (150 meters) of each building.

Pressure regulating valves--These valves are restricted on the fire protection water systems by NFPA No. 24, Outside Protection. When essential, they shall be installed on individual services rather than on the main piping. When pressure regulating valves (PRVs) are provided in mains supplying systems or parts of systems with fire hydrants, automatic sprinkler systems, or other installed fire protection, the following features shall be provided to safeguard against failures and to facilitate maintenance:

- Control valves on each side of PRVs
- Bypasses around PRVs

guidance FIRE PROTECTION/4 Systems

- Pressure relief valves on the low-pressure side of PRVs.

Water level controls--Manual controls, double-acting altitude valves, or other automatic devices shall be used to maintain the water level in elevated storage tanks. Altitude valves shall be arranged with bypasses.

Meters--When meters are installed on water distribution systems, they shall be Factory Mutual or Underwriters' Laboratories approved fire flow meters.

guidance LIFE SAFETY /1 Means of Egress**1. a. Occupant load (186-5-3.1.2)**

The occupant load factors to determine exit requirements for various occupancy classifications are given in the table below.

OCCUPANT LOAD FOR DETERMINING EXIT REQUIREMENTS

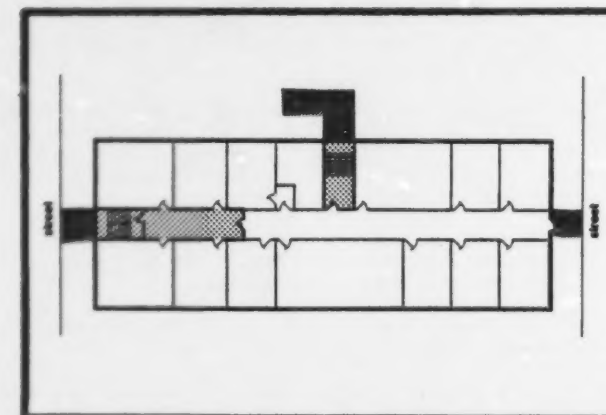
Occupancy Types	Square Feet per Person
Assembly	
Concentrated use (auditorium, dance floor)	7 (net area)
Less concentrated (conference, dining, etc.)	15 (net area)
Standing or waiting space	3 (net area)
Bench-type seating	18 in./person
Fixed seating	see Code text
Educational	
Classrooms	20 (net area)
Shops	50 (net area)
Day nurseries with sleeping facilities and child day care centers	35 (net area)
Health care/penal	
Sleeping departments	120 (gross)
Inpatient treatment departments	240 (gross)
Residential	
One- and two-family dwellings	no requirement
Apartments	200 (gross)
Hotels	200 (gross)
Dormitories	200 (gross)
Lodging/rooming houses	200 (gross)
Mercantile	
Street floor	30 (gross)
Upper floors	60 (gross)
Office areas	100 (gross)
Storage/shipping areas	300 (gross)
Covered malls	
First floor	30 (gross)
Second floor	60 (gross)
Business	100 (gross)
Industrial	100 (gross)

Note: In calculating exit requirements, open mezzanine or balcony occupant loads shall be added to the occupant load of the floor below. Occupancy types not listed (group and family day care centers and storage) have no special requirements.

guidance LIFE SAFETY /1 Means of Egress**b. Exit capacities**

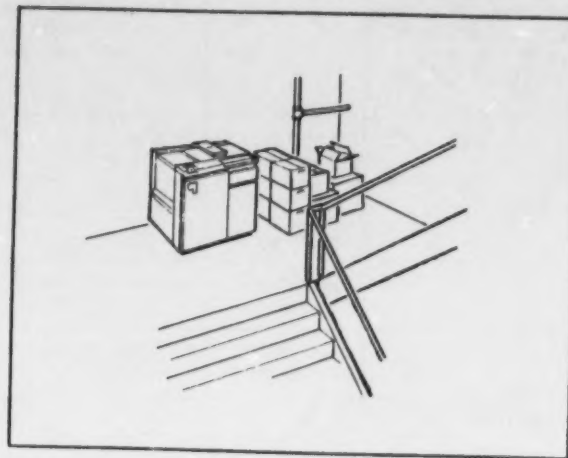
Means of egress components consist of three separate, distinct parts: the way of exit access, the exit, and the way of exit discharge. Each is illustrated in the following figure. (136) 5-1.2-1

- Exit Access 
- Exit 
- Exit Discharge 

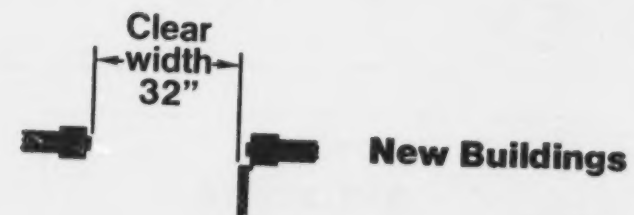
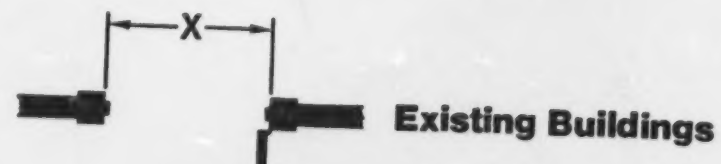
**EXIT COMPONENTS.**

guidance LIFE SAFETY /1 Means of Egress

No exit enclosure shall be used for purposes that would interfere with use as an exit, such as for storage or similar purposes. The impediments illustrated in the figure below are prohibited. (136) 5-1.3.3



HAZARDOUS LANDING.

**New Buildings****Existing Buildings**

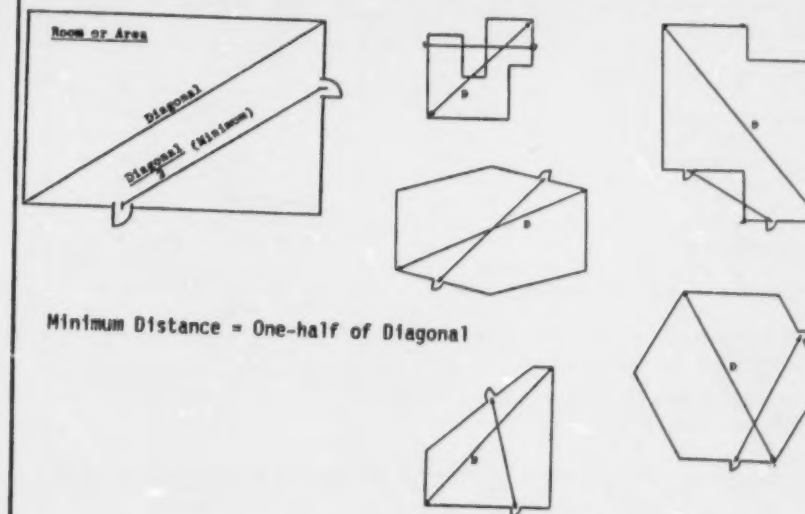
MEASURING UNITS OF EXIT WIDTH (DOORS).

guidance LIFE SAFETY /1 Means of Egress**C. Number of exits**

If two exits or two exit access doors are required in new construction, they shall be placed a distance apart equal to no less than one-half the length of the maximum overall diagonal dimension of the building or area to be served, measured in a straight line between exits. (See next figure.)

Exception: when exit enclosures are provided as the required means of egress and are interconnected by a corridor conforming to the requirements of reference 136, 5-1.3.4, exit separation can be measured along the line of travel within the corridor. Interlocking or scissor stairs shall be considered a single exit but may be credited for added capacity.

PROPOSED GUIDANCE ON THE FUNCTIONAL DEFINITION OF REMOTENESS (NFPA 101-LIFE SAFETY CODE TECHNICAL COMMITTEE-1984).



ARRANGEMENTS OF EXITS

guidance LIFE SAFETY /1 Means of Egress**d. Exit travel distances**

Travel distance to exits for new and existing business occupancies shall be no more than 200 feet. (60.96 meters).

An increase in the travel distance to 300 feet (91.44 meters) shall be permitted in a building protected throughout by an approved automatic sprinkler system.

See Guidance for instructions for measuring travel distance.

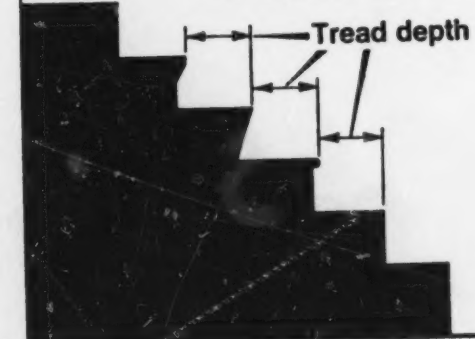
e. Exit components**New Stairs***

Minimum width clear of all obstructions, except handrails, which can project no more than 3-1/2 in. (8.89 cm) on each side, and stringers which can project no more than 1-1/2 in. (3.81 cm) on each side	44 in. (111.76 cm) 36 in. (91.44 cm) when total occupant load of all floors served by stairways is less than 50
Maximum height of risers	7 in. (17.78 cm)
Minimum height of risers	4 in. (10.16 cm)
Minimum tread depth	11 in. (27.94 cm)
Winders	See NFPA 101-5-2.2.2.4
Minimum headroom	6 ft. 8 in. (203.2 cm)
Maximum height between landings	12 ft. (365.76 cm)
Minimum dimension of landings in direction of travel	See NFPA 101-5-2.2.2.5
Doors opening immediately on stairs, without landing, at least width of door	No

*Exception: Existing stairs can remain in use or be rebuilt if they meet the requirements shown in the next part for existing stairs.

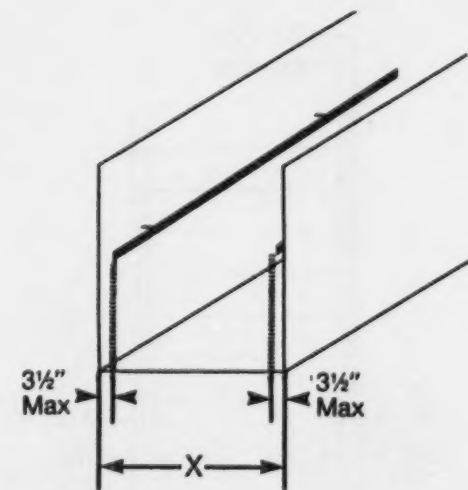
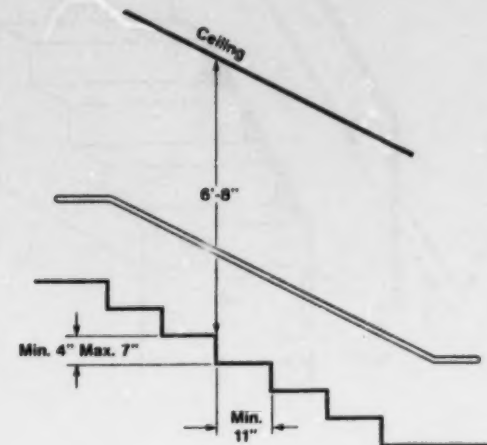
guidance LIFE SAFETY /1 Means of Egress**Existing Stairs**

Minimum width clear of all obstructions, except handrails, which can project no more than 3-1/2 in. (8.89 cm) on each side, and stringers which can project no more than 1-1/2 in. (3.81 cm) on each side	Class A 44 in. (111.76 cm)	Class B 44 in. (111.76 cm) 36 in. (91.44 cm) when total occupant load of all floors served by stairways is less than 50
Maximum height of risers	7-1/2 in. (19.04 cm)	8 in. (20.32 cm)
Minimum tread depth	10 in. (25.4 cm)	9 in. (22.86 cm)
Winders	See ref 136, 5-2.2.2.4.	See ref 136, 5-2.2.2.4.
Minimum headroom	6 ft. 8 in. (203.2 cm)	6 ft. 8 in. (203.2 cm)
Maximum height between landings	12 ft. (365.76 cm)	12 ft. (365.76 cm)
Minimum dimension of landings in direction of travel	44 in. (111.76 cm)	44 in. (111.76 cm)
Doors opening immediately on stairs without landing at least width of door	No	No

TREAD DEPTH MEASUREMENT.**5-2.2.2.10**

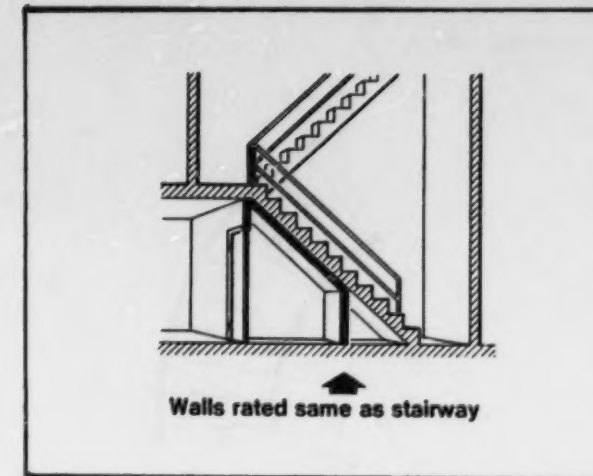
guidance LIFE SAFETY / 1 Means of Egress

STAIR DIMENSIONS.

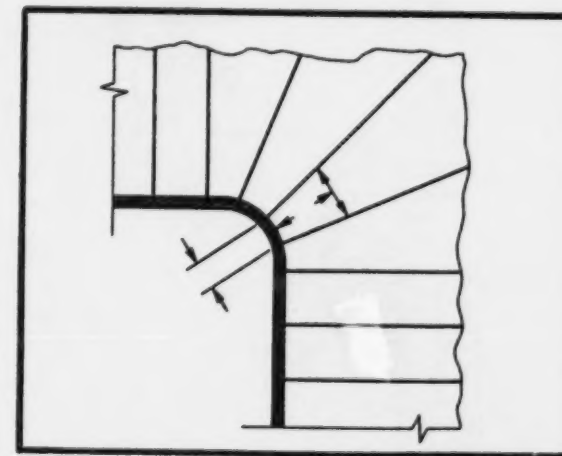


CORRIDORS, AISLES, RAMPS, AND EXIT PASSAGEWAYS.

guidance LIFE SAFETY / 1 Means of Egress



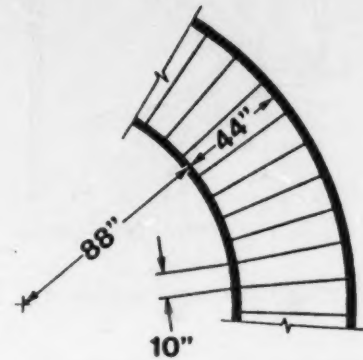
ENCLOSED USABLE SPACE IN EXIT ENCLOSURES.



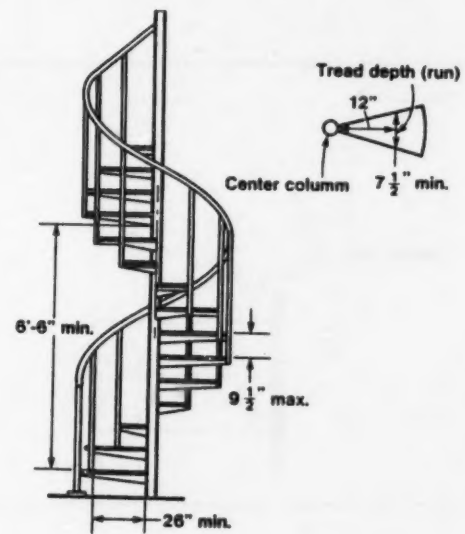
WINDERS (WHEN PERMITTED BY OCCUPANCY CHAPTER).

guidance LIFE SAFETY / 1 Means of Egress

STAIR DIMENSIONS, CONT'D.

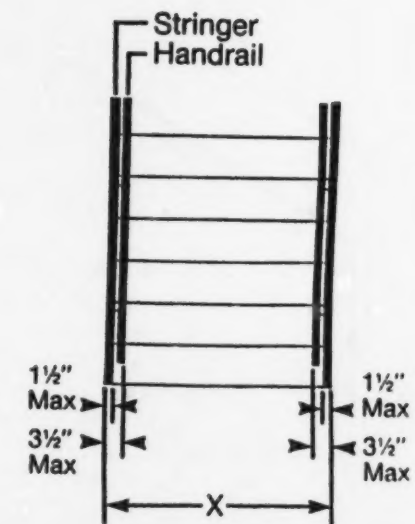
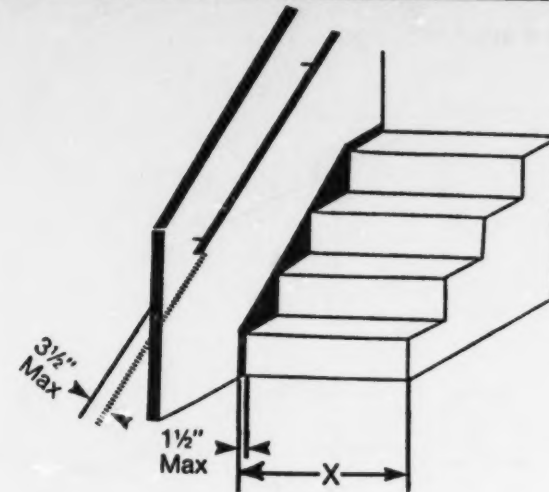


CURVED STAIRS.



SPIRAL STAIRS (WHEN PERMITTED BY OCCUPANCY CHAPTER).

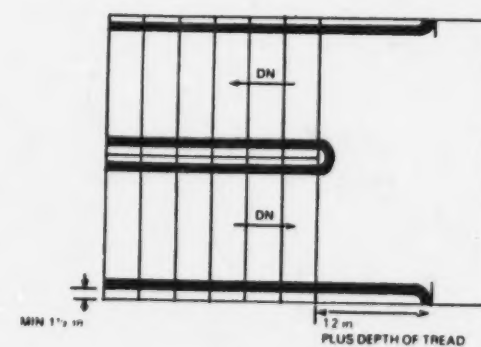
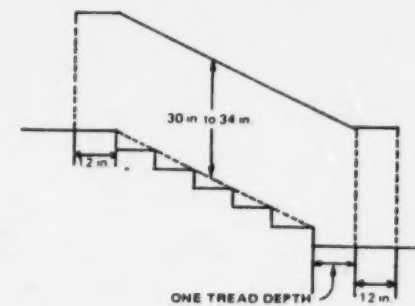
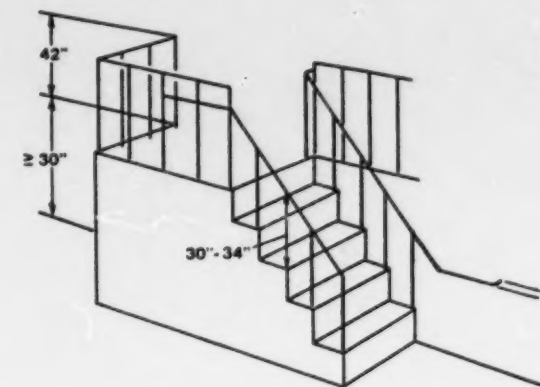
guidance LIFE SAFETY / 1 Means of Egress



MAXIMUM DISTANCE FROM HANDRAIL TO STRINGER.

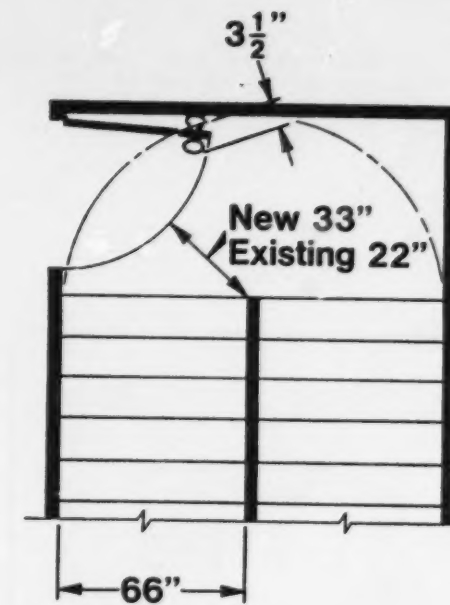
guidance LIFE SAFETY /1 Means of Egress

STAIR DIMENSIONS, CONT'D.



HANDRAIL DETAILS.

guidance LIFE SAFETY /1 Means of Egress



DOOR PROJECTION INTO MEANS OF EGRESS.

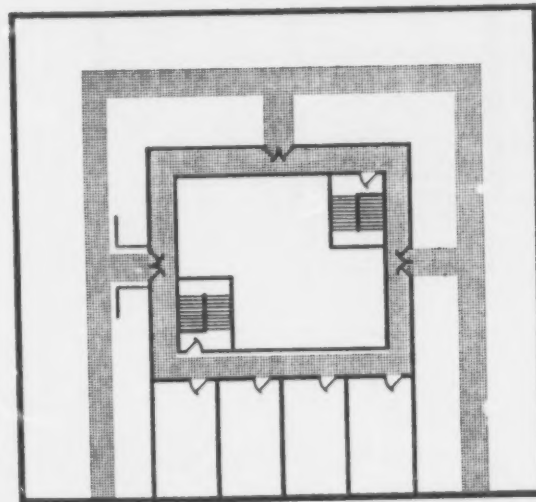
Exception: Stairway access doors in existing buildings may reduce landing width to no less than one unit of exit width.

guidance **LIFE SAFETY /1 Means of Egress****f. Exit marking**

When required by the occupancy, exit markings must be installed in accordance with this section.

Location

Exits and exit access when the exit or way to reach it is not immediately visible require an approved exit sign. The maximum distance is 100 feet from any point in the exit access to the nearest visible sign.



SIGN PLACEMENT.

guidance

guidance **LIFE SAFETY/2 Areas of Refuge**

2. a. Horizontal exits

A horizontal exit is a passageway to an area of refuge, either from one building to another, or from one area, through a barrier, to another area in the same building. The area of refuge must be on the same approximate level and must afford safety from fire and smoke.

Horizontal exits can be substituted for other exits (stairs, ramps, doors leading outside) if the total exit capacity of the other exits will be reduced no lower than half of what it would be without the horizontal exits.

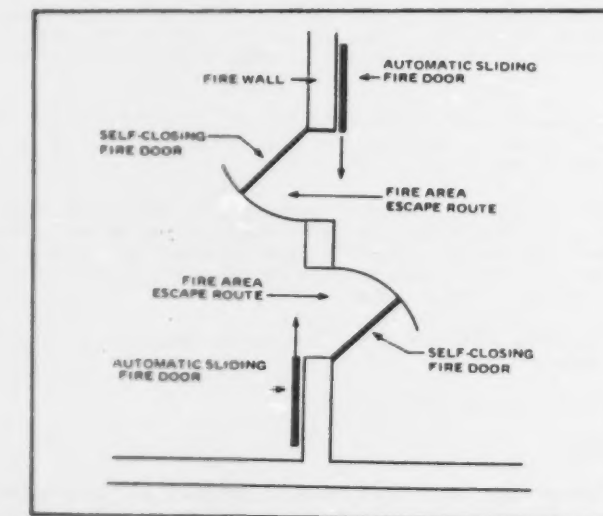
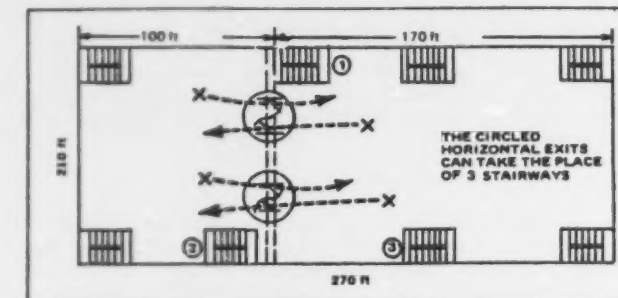
Fire compartments created by a horizontal exit must have an additional stairway, doorway, or other nonhorizontal exit for emergency egress (except in detention and correctional occupancies).

guidance **LIFE SAFETY/2 Areas of Refuge**

HORIZONTAL EXITS: SEPARATION.

Walls separating areas on either side of a related horizontal exit must have 2-hour construction continuous to ground.

Doors shall have a 1-1/2-hour rating and must swing in the direction of exit travel.



guidance LIFE SAFETY/3 Illumination

3. a. Exit lighting (177) 101-45

General

Means of egress shall be illuminated continuously during the time that occupancy conditions require an available exit. Artificial lighting shall be used at such places and for periods of time required to maintain illumination to the minimum foot-candle values specified in this chapter.

Means of egress floors shall be illuminated at all points, including angles and intersections of corridors and passageways, stairways, stair landings, and exit doors to values no less than 1.0 foot-candle, measured at the floor.

All required illumination shall be arranged so that the failure of any single lighting unit, such as the burning out of an electric bulb, will not leave any area in darkness.

The same equipment or units installed to meet the requirements of Section 5-10 in reference 177 may also serve to illuminate the means of egress, provided that all applicable requirements of this section for such illumination are also met.

Sources of illumination

Illumination of means of egress shall be from a source of reasonably assured reliability, such as a public utility electric service. When electricity is used as the source, the installation shall be done properly in accordance with the National Electrical Code, NFPA 70.

Battery-operated electric lights and any type of portable lamp or lantern shall not be used for primary illumination of the means of egress, but may be used as an emergency source to the extent permitted under "Emergency lighting."

No luminescent, fluorescent, or reflective material shall be permitted as a substitute for any of the required illumination specified here.

Exit lighting and exit signs shall conform to NFPA 101. Exits, exterior steps, and ramps shall be lighted well enough to prevent accidents. Separate lighting shall not be provided if street or other permanent lighting gives at least 1 foot-candle at the exit, steps, or ramp. (137) 7-6

See SB2, "Communication Station Buildings," for additional guidance.

b. Emergency lighting (177) 101-46

General

Emergency lighting for means of egress shall be provided for every structure when required in accordance with this section.

guidance LIFE SAFETY/3 Illumination

When maintenance of illumination depends on changing from one energy source to another, there shall be no appreciable interruption of light during the change-over. When emergency lighting is provided by a prime mover-operated electric generator, no delay more than 10 seconds shall be permitted.

System performance

Emergency lighting shall be arranged to maintain the specified degree of illumination for 1-1/2 hours in the event of normal lighting failure.

Electric battery-operated emergency lights shall use only reliable types of storage batteries provided with suitable facilities for maintenance in properly charged condition. Dry batteries shall not be used to satisfy these requirements. Electric storage batteries used in such lights or units shall be approved for their intended use and shall comply with the National Electric Code, NFPA 70.

An emergency lighting system shall be arranged to provide the required illumination automatically in the event of normal lighting interruption, such as any failure of the public utility or other outside electrical power supply, opening of a circuit breaker or fuse, or manual act(s), including accidental opening of a switch controlling normal lighting facilities.

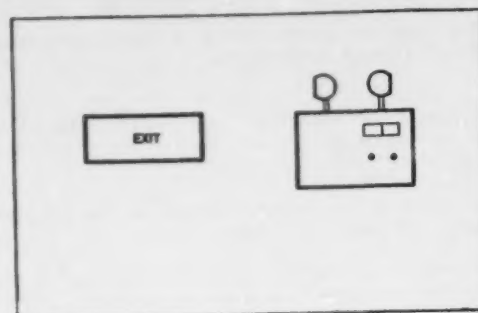
An emergency lighting system shall have either continuous operation or shall be capable of repeated automatic operation without manual intervention.

Emergency lighting systems shall be provided in accordance with the requirements of NFPA 101 (reference 177). In facilities with standby electric power systems, provisions shall be made to transfer the exit lighting system to the standby generating source. Emergency supplementary incandescent lighting of 2 foot-candles shall be provided along aisles and walkways in high bay areas where high intensity discharge lighting is used. In buildings with large electrical loads, full consideration shall be given to the possible economy of using higher voltages or frequencies for the lighting system. (136) 7-6

See SB2, "Communication Station Buildings, Electrical Lighting," for additional guidance.

guidance LIFE SAFETY/3 Illumination

EMERGENCY LIGHTING



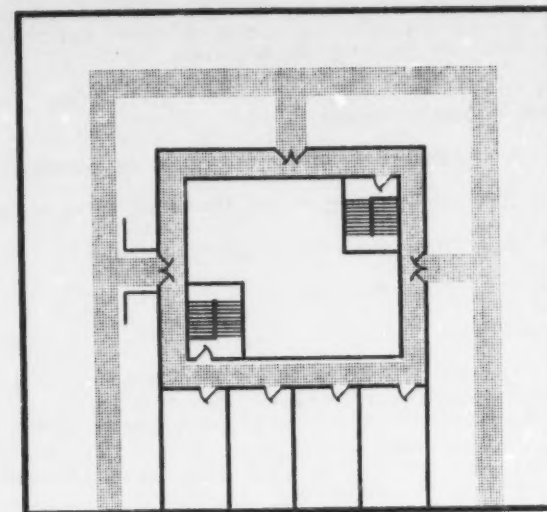
When the occupancy requires emergency lighting, all exit signs must be illuminated by the emergency lighting system. An exception is if self-luminous signs are used.

For exit marking, directional signs are those with an arrow and are used when the direction to the nearest exit is not readily apparent.

Special signs are required for exit marking when doors, passages, and stairways are likely to be mistaken for exits. These signs must read "NOT AN EXIT."

guidance LIFE SAFETY/3 Illumination

EMERGENCY LIGHTING, CONT'D.



DESIGNATED EXIT ACCESS

System performance

Emergency lighting must provide 1 foot-candle for 1-1/2 hours.

Batteries in battery-operated lights must be in accordance with the National Electrical Code, NFPA 70.

The system must provide lighting upon any failure, including that of the public utility.

guidance LIFE SAFETY/4 Smoke Removal

4. a. Smoke control systems

Air-handling systems including ducts can potentially spread fire, smoke, and hot gaseous products of combustion through the building or areas they serve. This hazard must be minimized by providing suitable fire doors or fire dampers where ducts pass through fire walls or fire partitions and by providing protection where ducts pass between floors vertically. Restrictions on the use of corridors and ceiling plenums for air handling are described in Guidance.

Air-handling, ventilation, and exhaust systems shall meet design requirements of the following:

NFPA No. 90A, Air-Conditioning and Ventilation Systems.

NFPA No. 90B, Warm Air Heating and Air-Conditioning Systems.

NFPA No. 91, Blower and Exhaust Systems.

NFPA No. 101, Life Safety Code.

1. Corridors.

Corridors shall not be used to replace ducts for air-handling (either supply or return) in hospitals, dispensaries, unaccompanied enlisted quarters, unaccompanied officer quarters, Navy temporary lodging facilities, schools, places of assembly, or windowless buildings. Corridors as air plenums shall be avoided in other occupancies.

2. Plenums

Ceiling plenums introduce a serious smoke and fire spread potential. Plenums may be used as an integral part of an air-handling system only if they conform to the requirements of NFPA No. 90A, Air-Conditioning and Ventilation Systems. Under no circumstances may combustible materials be located within the air plenum space. All electrical wiring passing through the space, including that for telephone and communications, shall be in metal conduit unless an automatic extinguishing system is provided.

3. Smoke removal systems

These systems are essential in windowless and multistory buildings to avoid undue exposure of occupants and to permit firefighting. However, economic considerations may preclude the provision of separate exhaust systems. Design features of combined ventilation and smoke removal systems include --

- Separate fan and duct systems for each floor in multistory buildings and for each fire area in windowless and multistory buildings

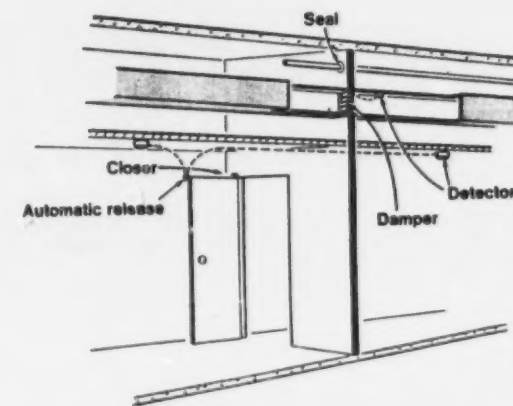
guidance LIFE SAFETY/4 Smoke Removal

- Dampers and ducts for direct discharge to outside from each return air system
- Separate manual control, readily accessible for fire department use, for all supply and return fans and dampers controlling discharge to the outside. Automatic operation of smoke removal systems by smoke detectors or by the fire alarm shall be provided when feasible.

Effective use of air-handling systems for smoke removal involves the following principles:

- Development of negative pressures in the fire or smoke area by shutdown of air supply fans and diversion of return air directly to outside
- Development of positive pressures in the adjacent areas by shutdown of return air fans.

If the area is protected with Halon 1301, it must have a forced ventilation exhaust system to the facility exterior for smoke and Halon removal.



SMOKE BARRIERS

SB4
Grounding / Bonding / Shielding

References:

- 15.b. MIL-HDBK-419, Grounding, Bonding, and Shielding for Electronic Equipments and Facilities (U.S. Dept. of Defense, July 1, 1981).
- 16. Design Practices for High Altitude Electromagnetic Pulse (HEMP) Protection (Defense Communications Agency, June 1981).
- 17. EMI Design, 1980.
- 24. Systems Engineering Specification 77-4, 1842 EEG SES 77-4 (Air Force Communications Command, January 1980).
- 120. EMP Engineering Practices Handbook, NATO File No. 1460-2 (October 1977).
- 198. "Tempest Countermeasures for Facilities Within the United States," National COMSEC Instruction, NACSI 5004 (January 1984) (Secret).
- 199. "Tempest Countermeasures for Facilities Outside the United States," National COMSEC Instruction, NACSI 5005 (January 1985) (Secret).

SB4 GROUNDING, BONDING, AND SHIELDING

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GROUNDING, BONDING, AND SHIELDING

function
To improve equipment operating efficiencies and increase safety, it is necessary to effectively ground, bond, and shield (1) electrical/electronic equipment and (2) buildings and structures (facilities).
policy / sop
1. Grounding The facility ground system forms a direct path of known low impedance between earth and various power and communication equipment. Effectively, this means that no voltage differentials exist on the ground plane above a value that will produce noise or interfere with communication circuits. Personnel and equipment are protected when, during an electrical ground fault, the ground system provides a path for rapid operation of protective overcurrent devices, or, during a lightning stroke, provides current with a low impedance path to earth. Personnel and equipment protection against power fault currents, static charge buildup, and lightning flashover should be provided both by protective ground wire and by bonding all normally non-current-carrying metal objects, including structural steel support members, to the facility ground system. This ground system also provides low impedance paths between facility buildings and structures, as well as between equipment within the facility and the earth. This minimizes the effects of noise currents. The facility ground system consists of the following electrically interconnected subsystems: a. An earth electrode subsystem, including the various interconnected metallic elements such as fuel tanks, tower bases, fences, and water pipes. (15a) 6 An earth electrode subsystem shall be installed at each C-E facility. Such a system provides a low-resistance path to earth for lightning and power fault currents and insure that there are no hazardous voltages between the facility and earth. This subsystem shall be able to dissipate to earth the energy of direct lightning strokes without degrading itself. The system shall also interconnect all driven electrodes and underground metal objects of the C-E facilities, including the emergency power plant. The earth electrode subsystem shall not degrade the quality of signals in the signal circuits connected to it. (15a) 8 b. An equipment-fault-protection subsystem The fault-protection subsystem is a separate grounding conductor. It protects personnel and equipment from power fault currents and static charge buildup. (15a) 10

policy / sop

c. A lightning protection subsystem

Lightning protection shall be provided as required for buildings and structures in accordance with the National Fire Protection Association (NFPA) number 78. All electrical/electronic equipment which is part of, or is in support of, C-E facilities shall be protected. (15a) 15

d. A signal reference subsystem (15a) 6

A signal reference subsystem shall be installed at each facility. Signal circuits are grounded to control static charges and noise and to establish a common reference for signals between sources and loads. The goal is to ground facilities and equipment so as to minimize interference between items of equipment. Where units are distributed throughout the facility, the signal reference ground subsystem shall consist of one of the following:

1. An equipotential ground plan for higher frequencies

The more extensive the equipotential ground plan, the more effectively it can minimize differences in potential between interconnected equipment at higher frequencies.

2. A single point ground for lower frequencies

A lower frequency network shall be installed at facilities employing frequency equipments from d.c. to 30 kilohertz and in some cases to 300 kilohertz. The purpose of this network is to isolate lower frequency signals from all other ground networks, including structural, safety, lightning and power grounds. The network prevents stray currents (primarily 60 hertz) from developing voltage potentials between points on the ground network. (15a) 19

3. An equipotential ground plan for hybrid frequencies--a combination of higher and lower ones

A hybrid frequency signal network is defined as a combination of both higher and lower frequencies. Where required, an isolated, single-point signal grounding network should be provided for lower frequency equipment. High frequency equipment is grounded to the equipotential plane. (15b) 1-141

The signal grounding networks in a facility must be designed and installed so that it controls interference coupling. Not all circuit and system noise problems will be solved even with correctly designed networks, either lower or higher frequency. Additional measures--such as reducing the levels of the sources of interference through shielding, filtering, or alternative design; using common mode rejection techniques; and implementing other coupling control techniques--frequently will be necessary to limit the noise level in system circuits to a noninterfering level. (15b) 1-134

policy / sop

2. Bonding

A bond is an electrical union between two metallic surfaces that is used to provide a low-impedance path between these surfaces. Bonding is the procedure by which the conductive surface of a subassembly or component is electrically connected to another. It prevents the development of electrical potentials between individual metal surfaces for all frequencies capable of causing interference. (15a) 7

High-quality bonds between conducting elements throughout the facility are essential for the effective functioning of all grounding and shielding networks. Thus thorough consideration must be given to bonds and bonding throughout the design and construction of a facility. A bonding resistance of 1 milliohm indicates that a high quality junction has been achieved. (15b) 1-154

3. Shielding

Shielding is required in electrical and electronic equipment to prevent the equipment from propagating interference and to protect it from the effects of interference propagated by other electronic devices. (15a) 7

The term "TEMPEST" flags the system as processing information related to national security and establishes the need for additional, site-specific facility alterations and improvements.

NCSC-4, "National Policy on Control of Compromising Emanations," exists to prevent the loss of national security information through compromising emanations. To achieve this objective, the effective edition of NACSIM 5100 was developed to provide compromising emanations requirements for new equipment/system development. In some cases, adequate TEMPEST protection may be achieved without full compliance with NACSIM 5100. NACSI 5004 provides procedures for determining countermeasures needed for classified information processors used within the U.S.; procedures for processors used outside the U.S. are contained in NACSI 5005. (198) 1

- a. The procedures defined within NACSI 5004 shall be used by all departments and agencies to determine the countermeasures to be applied to equipments/facilities which process national security information within the U.S. Appropriate verification procedures will be used to demonstrate TEMPEST countermeasures acceptability. These procedures will be dictated by the countermeasures employed and will be arranged by order of importance so that it focuses limited TEMPEST resources on those areas deemed most vulnerable to hostile exploitation. No countermeasures are required for systems which do not process classified information.

Where the use of NACSIM 5100 approved devices is indicated, every effort shall be made to use equipments listed on the SCOCE Preferred Products List (PPL).

policy / sop

- b. The requirements shall be used by all departments and agencies to determine the countermeasures to be applied to equipments/facilities which process national security information outside the U.S. Appropriate verification procedures will be used to demonstrate TEMPEST countermeasures acceptability. These procedures will be dictated by the countermeasures employed and will be arranged by order of importance so that they focus limited TEMPEST resources on those areas deemed most vulnerable to hostile exploitation.

Where the use of NACSIM 5100 approved devices is indicated, every effort shall be made to use equipments listed on the SCOCE Preferred Products List (PPL). (199) 2

REQUIREMENTS.

- (1) For each equipment/system/facility processing national security information, both a hazard and a risk factor shall be determined using the procedures of the Annex.
- (2) The TEMPEST countermeasures to be applied shall be determined by using the hazard and risk factors.
- (3) The National Security Agency (NSA) shall, on a semiannual basis, publish a listing of equipments and corresponding TEMPEST information. This document, entitled "TEMPEST Data for Information Processing Equipment," will contain data concerning NACSIM 5100 compliance, PPL status, Equipment Zone assignments, and required controlled space determinations.
- (4) A higher level countermeasure can be used, but it should be recognized that the implementation cost could be higher. In the absence of specific details of cost or operational impact, the indicated countermeasure should be implemented. Use of a higher level countermeasure should be coordinated with the department or agency TEMPEST authority. (199) 2

issues and assumptions**Grounding****1. Site-specific grounding system**

The grounding system should be tailored to reflect the characteristics of the site and the requirements of the facility. (10) 4-507 The relationship between the performance of an electronic system and the specific value of the resistance of the earth ground is unclear. The value of 10 ohms earth electrode resistance is a carefully considered compromise between overall fault and lightning protection requirements and the estimated relative cost of achieving the resistance in typical situations. In locations with high soil resistivities, achieving 10 ohms could be very expensive. In such locations, examine all elements of the site, consider the requirements of the planned facility, and then choose the best compromise based on soil conditions, relative costs, and so forth. (15b) 1-2

2. Selection of electrode configuration

Determine what type of earth electrode subsystem is more appropriate for the facility (such as complex, building, structure, transformer bank, and substation). The directed configuration is a ring ground as outlined in MIL-STD-188-124. If this configuration cannot be used, however, alternate configurations meeting the requirements may be developed. Typical suggested alternatives are:

- a. Change the number of ground rods.
- b. Use longer ground rods.
- c. Use horizontal wires or grids instead of vertical rods.
- d. Lower the soil resistivity through chemical enhancement (salting). (15b) 1-6

3. Grounding, bonding, and shielding as part of the equipment design criteria

The design of the equipment should emphasize careful grounding, bonding, and shielding along with other interference and noise control measures. This will allow compatible operation within the electronic system in which the equipment is installed. This emphasis must continue during the manufacture, installation, and operation of the equipment or system. For example, during manufacture, careful attention should be given to the routing of cables, the choice and mounting of cable connectors, the selection of signal and ground conductors, the correct implementation of all bonds within the equipment, and so on. When the piece of equipment is installed, the configuration of the facility ground networks (for a detailed description of these networks, see Section 1.5) and the integrity of the shields within the facility must be maintained. Correspondingly, the ground networks and shields in the facility should not be allowed to degrade during the operation of equip-

issues and assumptions

ment. For example, ground connections should not be randomly changed in efforts to improve equipment operation without considering how such changes will affect the overall system. This recommendation applies to both internal and external changes to the equipment. (15b) 3-1

4. Chemically treating the soil (87) Vol 3, 39

An electrode's resistance can be reduced by adding ion-producing chemicals to the soil immediately surrounding the electrode. However, these chemicals should be used with discretion due to the corrosive effects on the earth electrode subsystem. The better known chemicals in the order of preference (least corrosive) are:

- a. Magnesium sulfate (MgSO_4) - epsom salts.
- b. Copper sulfate (CuSO_4) - blue vitriol.
- c. Calcium chloride (CaCl_2).
- d. Sodium chloride (NaCl) - common salt.
- e. Potassium nitrate (KNO_3) - saltpeter.

Magnesium sulfate, the material most commonly used, combines low cost with high electrical conductivity and low corrosivity on a ground electrode or plate. NaCl and KNO_3 are not recommended as either will require that greater care be given to protecting against corrosion. Additionally, nearby metal objects, even though not related to grounding, will require treatment to prevent damage by corrosion. Therefore, NaCl or KNO_3 should be used only as the last resort.

issues and assumptions**Shielding****1. Determining the shielding requirements for a facility**

The electromagnetic environment at the planned location should first be surveyed. This threat environment should then be compared with the response properties or susceptibilities of the equipment to be located in that environment. If shielding is indicated, then either it should be provided as part of the facility or the equipment shielding should be upgraded. (15b) 1-164 Structural shielding may be necessary if sufficient shielding cannot be incorporated into the equipment or its installation (power and signal wiring and cabling) to prevent interference. Such structural shielding can be used for:

- a. RFI/EMI (radio frequency interference/electromagnetic interference), where the requirement is determined by the equipment sensitivity and the ambient field level.
- b. TEMPEST requirements, where there are potential compromising emissions from equipment used to process classified information.
- c. EMP/HEMP requirements (see "EMP/HEMP Protection"), where protective measures are based on intercepting the incident energy and dissipating it or reflecting it away from the threatened facility. (15b) 1-186 A structure meeting EMP/HEMP requirements will quite often be satisfactory for (a) and (b), although some specialized shielding is needed for TEMPEST.

The final decision will be based on a trade-off between the known (or estimated) shielding requirements and the relative cost of providing it. Shielding/susceptibility requirements of C-E equipment should meet the specifications of MIL-STD-461B. (15b) 1-164

2. Determining shielding protection techniques

The shielding protection that can be designed into installations is a function of the EMP/HEMP or EMI (electromagnetic interference) interference in the various environmental zones and the natural protection available in each zone. The shielding protection techniques are those practices that can be implemented in each environmental zone to protect against interference. (120) 3-11 In essence, this involves three zones, defined as follows: zone 0, the outside world; zone 1, inside the structural shield (the internal environment); and zone 2, the equipment environment. The boundary between zones 0 and 1 is the facility shield, and the boundary between zones 1 and 2 is the equipment framework and cabinets. The concept was developed originally for EMP shielding but it applies directly to EMI shielding also. See "EMP/HEMP Protection" for additional information on shielding.

issues and assumptions**3. Equipping all power lines supplying shielded areas with power line filters**

Power line filters are often specified to meet attenuation requirements according to MIL-STD 220 tests. However, MIL-STD 220 seems to be used with some reservation, since a 50-ohm load is specified for testing. A typical installation is very rarely 50 ohms; if the filter is of the reactive type the test results may not represent the situation accurately.

requirements	criteria	commentary
GROUNDING 1. Earth electrode subsystem interconnecting all site metallic structures 2. Fault protection subsystem to provide personnel and equipment protection against power fault currents and static charge build-up (15a) 10 3. Lightning protection subsystem to provide structures with minimum protection against direct lightning strikes (15b) 1-23 4. Signal reference subsystem to control static charges and noise and to give signals a common reference between sources and loads	1. a. An interconnecting ground rod system (including many interconnecting cable and ground rods for most installations). b. Grounding wells and interconnecting cable to provide access points for periodically checking the interconnected ground rod system. 2. a. Grounding conductor. b. Exposed metallic elements of electrical and electronic equipment must be connected to a ground. c. Metallic pipes and tubes (including a conduit) and their supports should be electrically continuous and bonded to the facility ground system at least at one point. d. Standby a.c. generators should be grounded as part of the fault-protection subsystem. 3. Lightning protection systems can be designed either integral with the building or separately. a. An air terminal must be provided to intentionally attract the leader stroke, and a path must be established that connects the terminal to earth with such a low impedance that the discharge follows it in preference to any other path. b. A low-resistance connection must be made with the earth electrode subsystem. The connection must include a low impedance interface between the earth electrode subsystem and the earth. c. Lightning-generated transient surge protection. 4. a. Signal reference system for higher frequencies 1. Establish an equipotential plane in order to create a multipoint ground system. 2. Select a type of equipotential plane relevant to the building construction components. b. Signal reference system for lower frequencies 1. Centrally locate and install a main ground plate. 2. Install a trunk ground cable, branch ground plates and cables, and feeder ground plates. c. Hybrid systems (combinations of higher and lower frequencies) utilize either a multipoint ground system or a single point ground plate, according to conditions.	

requirements	criteria	commentary
	d. For crypto gear the red signal reference subsystem isolates an equipotential plane from the black equipotential plane.	
BONDING 1. Low-impedance electrical connections throughout the grounding systems	1. Creating and maintaining low-impedance electrical connections involves: a. Appropriate material selection. b. Adequate surface preparation. c. Reliable bonding procedures.	
SHIELDING 1. Containment of radio frequency interference (RFI) with equipment by a comprehensive shielding of all DCS electrical and electronic equipment from each other and other outside devices 2. Containment of emanations from telecommunications to prevent the potential security breach of allowing unauthorized personnel to obtain sensitive message information surreptitiously	1. A shielding system to minimize the effects of equipment RFI involves: a. A building layout to optimize inherent facility shielding conditions. b. Appropriate location of electronic equipment and signal cables. c. Effective shielding materials and construction components. 2. Criteria for TEMPEST shielding and grounding procedures are available in National Security Agency (NSA) documents. A shielding system to contain all telecommunication emanations involves: a. Selection of effective enclosure materials. b. Reliable construction details to maintain shielded integrity. c. Isolators and filters.	

guidance GROUNDING/1 Earth Electrode System**1. a.** An interconnecting ground rod system

1. Most installations will require many interconnected ground rods. The rods and interconnecting cable comprising the earth electrode subsystem should have the following parameters.

- All structural extensions, separate facilities, or equipment protrusions (such as antenna elements or towers) should have a continuous earth electrode subsystem enclosing each facility or should have individual earth electrode subsystems connected together.
- All incidental, buried, or metallic structures near the earth electrode subsystem should be connected to the subsystem. This will reduce the danger of potential differences during lightning or fault protection and the resistance to the earth. Such additions to the earth electrode subsystem should include the rebar in concrete footings and buried tanks and pipes. (15b) 1-14

2. Determine what type of earth electrode subsystem is most appropriate for the facility (complex, building, structure, transformer bank, substation, and so forth). The directed configuration is a ring ground (outlined in paragraph 5.1.1.3 of MIL-STD 188-124). If this configuration cannot be used, the following alternate configurations meet these requirements.

- Establish the primary functional requirements to be met by the earth electrode subsystem. For example:

Lightning--For a facility located in an area of high lightning incidence or that has a high degree of exposure to lightning (or both), the earth electrode subsystem must safely dissipate the lightning energy without melting conductors or overheating the soil. Also, the subsystem must minimize step voltages in areas where personnel are present.

Impulse properties and RF impedance characteristics--If the earth electrode subsystem must serve also as an antenna counterpoise, it must have low-RF impedance properties. Where EMP protection is necessary, low-impedance radials should be incorporated into the earth electrode subsystem.

Mobility--Usually mobile facilities or temporary transportable facilities will not justify the installation of an extensive fixed electrode subsystem. For such facilities, install only a basic system capable of providing the minimum acceptable lightning and personnel fault protection.

guidance GROUNDING/1 Earth Electrode System

Resistance--At fixed C-E facilities, the earth electrode subsystem should exhibit a resistance to earth of 10 ohms or less. If 10 ohms is not economically feasible by the ring ground, alternate methods should be considered. See Paragraph 5.1.1.3.2 of MIL-STD 188-124. Resistance measurements using the fall-of-potential method shall be carried out in 3-month increments for 12 months following installation. Measurements shall be conducted in 9-month intervals after the first year.

- Evaluate local conditions

Soil resistivity--Is soil resistivity low (less than 5000 ohms per centimeter), average (5000 to 20,000 ohms per centimeter), or high (more than 20,000 ohms per centimeter)? The higher the soil resistivity, the more complex (and expensive) will be the electrode subsystem necessary to achieve 10 ohms resistance.

Moisture content--Is the water table near the surface or far below grade, and is it subject to large seasonal variations? If possible, design the earth electrode subsystem so that it makes and maintains contact with soil that it make and maintains contact with soil that stays damp or moist year round. Penetration of the permanent water table is highly desirable.

Frost line--How deep does the frost line extend, even during the coldest periods? The resistivity of soil rises greatly as the soil temperature drops below 32°F. Thus, for maximum stability of electrode resistance, the subsystem should penetrate far enough into the soil so that contact is always maintained with unfrozen soil. The earthing techniques described in these volumes do not apply directly to permafrost. In permafrost, fault protection must be provided through the use of metallic returns accompanying the power conductors. This insures the existence of a return path to the transformer or generator. The protection of personnel calls for an even greater emphasis on the bonding of all metal objects subject to human contact together and to the power system neutral. Because of the high resistance of permafrost, stray earth currents can be expected to be minimal, with consequently reduced concern with interfacility power frequency noise problems. If problems from earth current noise exist, the common-mode rejection techniques described in the following guidance section apply.

guidance GROUNDING/1 Earth Electrode System

Rock formation--Are major rock formations near the surface, and are they large enough to influence the design and layout of the earth electrode subsystem? In regions of shallow bedrock, it may be necessary to use horizontal grids, wires, or plates instead of vertical ground rods. Large rock outcroppings or subsurface boulders may force alternate routing of conductors or the placement of rods. The expense of drilling holes in rock to insert rods or lay wires need not be incurred, since the resistivity of rock is so high that generally the rods or wires would be ineffective.

Architectural layout--Design the electrode subsystem so that it will not be materially influenced by the weather shielding effects of parapets and overhangs. Lightning down-conductor placement and routing will frequently be influenced by architectural considerations. Design the electrode subsystem to accommodate such considerations by providing convenient connection points near the down conductors. Route the ground subsystem counterpoise cable near down conductors to avoid long extensions between the down conductor and the effective grounding point. Configure the electrode subsystem such that convenient connections are possible between the electrode subsystem, power grounding conductors, and signal ground system terminations inside the facility.

Landscape features--Preferably locate ground subsystem conductors under sodded areas or other areas covered with vegetation. Locate conductors to take maximum advantage of the wetting effects of runoff or drainage water from the roof, parking lots, and so forth. Try to avoid placing major portions of the earth electrode subsystem under extensive paved areas such as roads and parking lots.

guidance GROUNDING/1 Earth Electrode System

- Consider the relative advantages and disadvantages in the following table, choose a basic type of electrode most appropriate for meeting the functional requirements of the facility at the site under construction.

RELATIVE ADVANTAGES AND DISADVANTAGES OF THE PRINCIPAL TYPES OF EARTH ELECTRODES

Type	Advantage	Disadvantage
Ring ground	Straightforward design. Easy to install (particularly around an existing facility). Hardware readily available. Can be extended to reach water table.	Low impulse impedance. Not useful where large rock formations are near surface.
Horizontal bare wires (radials)	Can achieve low resistance where rock formations prevent use of vertical rods. Low impulse impedance. Good RF counterpoise when laid in star pattern.	Subject to resistance fluctuations with soil drying.
Horizontal grid (Bare Wire)	Minimum surface potential gradient. Straightforward installation if done before construction. Can achieve low resistance contact in areas where rock formations prevent use of vertical rods. Can be combined with vertical rods to stabilize resistance fluctuations.	Subject to resistance fluctuation with soil drying if vertical rods not used.
Vertical rods	Straightforward design. Easiest to install (particularly around an existing facility). Hardware readily available. Can be extended to reach water table.	High impulse impedance. Not useful where large rock formations are near surface. Step voltage on earth surface can be excessive under high fault currents or during direct lightning strike.
Plates	Can achieve low resistance contact in limited area.	Most difficult to install.
Incidental electrodes (utility pipes, building foundations, buried tanks)	Can exhibit very low resistance.	Little or no control over future alterations. Must be employed with other manufactured electrodes.

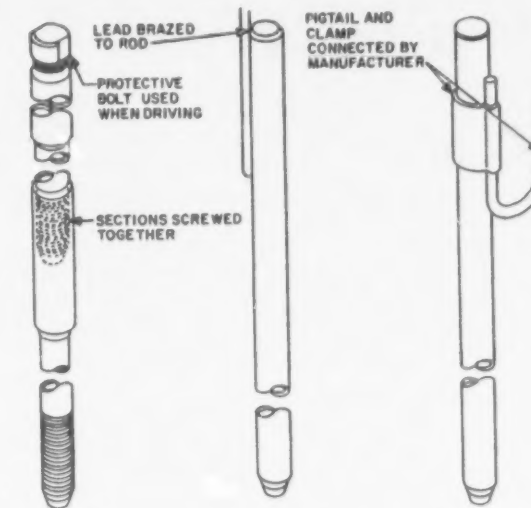
- Estimate the relative cost of each type of configuration to meet the objectives. Include the cost of materials, installation costs, and relative maintenance and upgrading costs.

guidance GROUNDING/1 Earth Electrode System

- At each facility supplied by electric power, at least one ground rod should be installed near the service disconnection and bonded to the earth electrode system. If the transformer is located on the site, a bare 1/0 AWG wire or cable should interconnect the ground rod at the transformer with the earth electrode subsystem at the service disconnect.
- Every facility requires an earth electrode subsystem to protect against lightning.
- The number of ground rods required at a given location will be determined by the resistivity of the soil and the configuration of the installation. Three-meter (10-foot) ground rods installed at 20-foot intervals around the perimeter of the structure utilize the effective radius of the rod while providing several points of contact with the earth. If longer rods are needed to reach the water level, to contact lower resistivity soils, or to penetrate below the frost line, greater spacings may be employed. The nominal spacing between rods should be between one and two times the length of the rod. However, a ground rod must be placed near each lightning down conductor. Therefore, spacings should be limited to not more than 50 feet in order to conform to lightning protection requirements.
- The rods and interconnecting cable comprising the earth electrode subsystem should be positioned 0.6 to 1.8 meters (2 to 6 feet) outside the dripline of the building or structure. This will insure that rain, snow, and other precipitation wets the earth around the rods.
- For facilities which do not conform to a rectangular or square configuration, lay out the rod field to follow the general perimeter of the structure.
- If two or more structures or facilities are located in the same general area and are electrically interconnected with signal, control, and monitor circuits, either provide a common ground rod counterpoise system or interconnect the separate electrode systems with buried bare cables. A common example of an installation where separate structures are involved is a radar or communications site where the equipment shelter is next to the antenna tower. Signal cables (both coaxial and waveguide), control cables, and power lines typically run between the tower and the shelter. Since the tower is taller than the shelter, it is more susceptible to lightning strikes. To minimize voltage differentials between the two structures, the facilities should effectively share a common earth electrode subsystem. Separate structures spaced closer than 6 meters (20 feet) should have a common earth electrode subsystem installed that encircles both facilities (see the following figure). The next figure shows the recommended arrange-

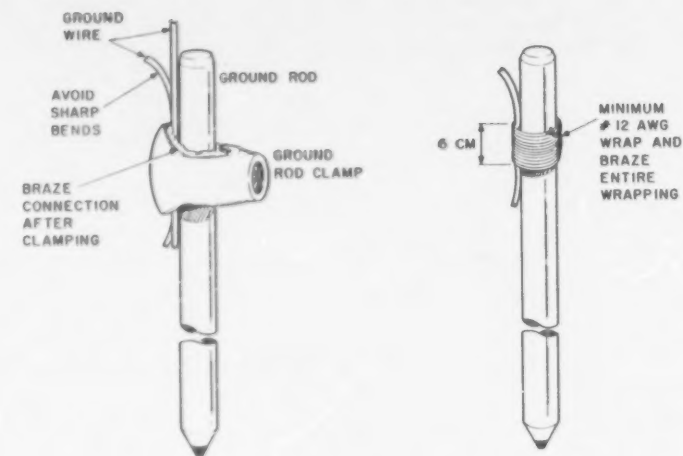
guidance GROUNDING/1 Earth Electrode System

ments when separations of 6 meters (20 feet) or more are encountered. The buried bare cable may also serve as a guard for buried signal or power cables.



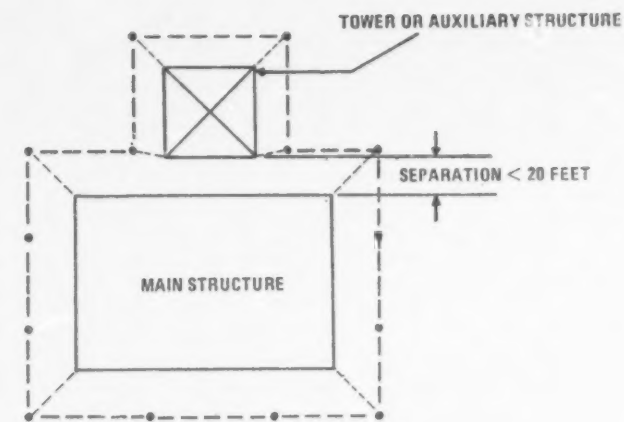
GROUNDING RODS. (40) 12-4.

- The tops of ground rods should be at least 0.3 meters (1 foot) below grade level. This will minimize resistance variations caused by surface drying of the soil and by the freezing of the soil during winter, and will also minimize the possibility of mechanical damage to ground rods, connections, and interconnecting cables. Bury the bare 1/0 AWG interconnecting cable at least 0.6 meters (two feet) below grade level.
- If the subsystem is installed after foundations are poured, cables are installed, utility pipes installed, and so on, make proper provisions for making the needed interconnections between the water system, lightning down conductors, structural steel, buried lines and cables, and electrodes.

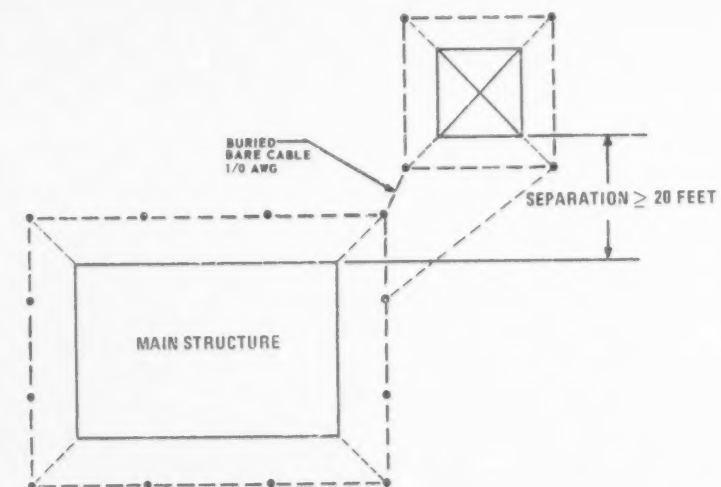
guidance **GROUNDING/1 Earth Electrode System****NOTES:**

1. CORRODED AND DIRTY RODS SHOULD BE CLEANED WITH ACID AND WASHED, THEN BRAZED OR WELDED.
2. BRAZED, WELDED, BOLTED, AND CRIMPED BONDS ARE ACCEPTABLE ABOVE GROUND.

CLAMPED AND BRAZED GROUND ROD CONNECTION. (1) 62

guidance **GROUNDING/1 Earth Electrode System**

ELECTRODE CONFIGURATION FOR ADJACENT STRUCTURES.



CONFIGURATION FOR CLOSELY SPACED STRUCTURES.

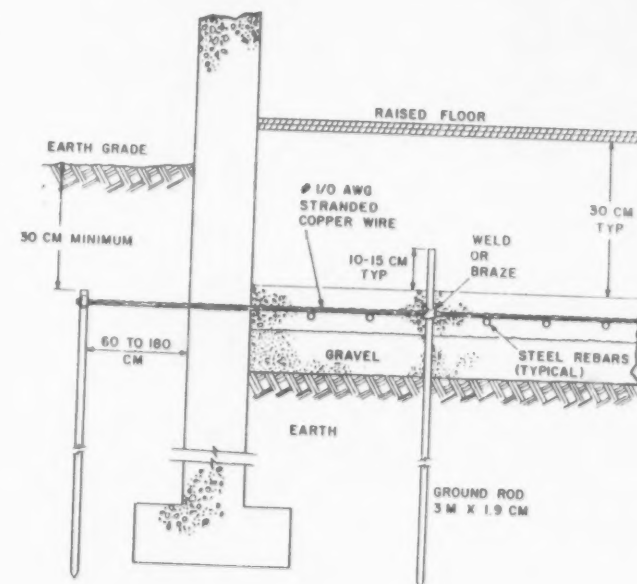
guidance GROUNDING/1 Earth Electrode System

3. Consider using cathodic protection. (87) Vol 3, 40 When two metals of different types are immersed in wet or damp soil, a basic electrolytic (galvanic) cell is formed. A voltage equal to the difference of the metals' oxidation potentials will develop between the cell's two electrodes. If these electrodes are connected together through a low-resistance path, current will flow through the electrolyte, eroding the anodic member of the pair. Unfortunately, factors that help establish a low resistance to earth also foster corrosion. Low resistance soils with a high moisture level and a high mineral salt content provide an efficient electrolyte cell with low-internal resistance. Relatively large currents can flow between short-circuit electrodes (such as copper ground rods connected to steel footings or reinforcing rods in buildings) and quickly erode away the more active metal of the cell. Three basic techniques can be used to lessen the corrosion rate of buried metals.

- One technique is to insulate the metals from the soil. Insulation interrupts the current path through the electrolyte and prevents erosion of the anode. Of course, insulation is not an acceptable corrosion preventive for earth electrodes.
- The second technique for reducing galvanic corrosion is to avoid using dissimilar metals at a site. For example, if all metals in contact with the soil are of one type (such as iron, lead, or copper), galvanic corrosion is minimized. However, each of these materials has unique, desirable properties (such as weight, cost, conductivity, ductility, and strength), and thus, none can simply be dismissed from consideration for underground applications.
- The third technique for combatting corrosion caused by stray direct currents and dissimilar-metal unions is commonly called "cathodic protection." Cathodic protection can be implemented by using sacrificial anodes or an external current supply to counteract the voltage developed by oxidation. Sacrificial anodes containing magnesium, aluminum, manganese, or other highly active metal can be buried in the earth nearby and connected to an iron piling, steel conduit, or lead cable shield. The active anodes will oxidize more readily than the iron or lead and will supply the ions required for current flow. If the sacrificial anodes are replenished at appropriate intervals, the life of the protected elements is significantly prolonged. Sacrificial anodes protect limited areas. Long cable or conduit runs can be protected by applying a d.c. voltage to the metal relative to the surrounding soil. The external d.c. source supplies the ionization current that would normally be provided when the cable sheath or conduit oxidizes.

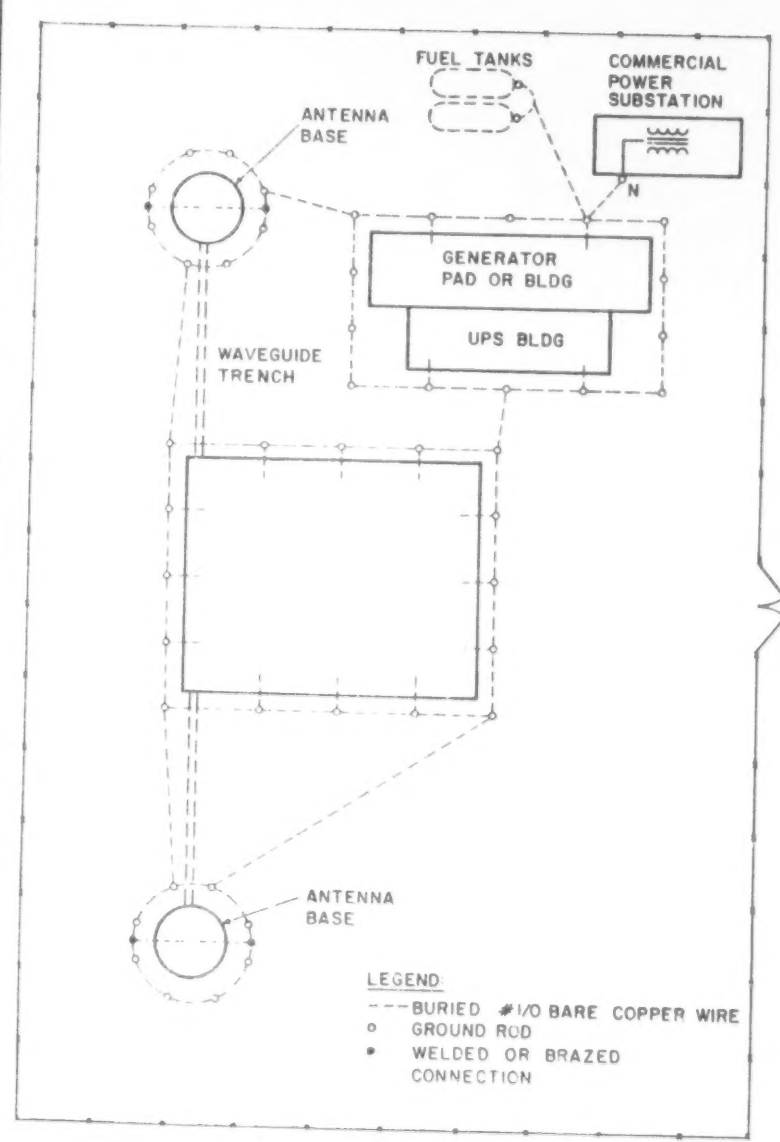
guidance GROUNDING/1 Earth Electrode System

- In regions of low soil resistivity, corrosive atmospheres near seashores, or near sources of large direct currents such as electroplating facilities, cathodic protection may be necessary to prolong the life of foundations, underground cable, or other elements in contact with the soil.



TYPICAL GRID GROUND ELECTRODE.

guidance **GROUNDING/1 Earth Electrode System**



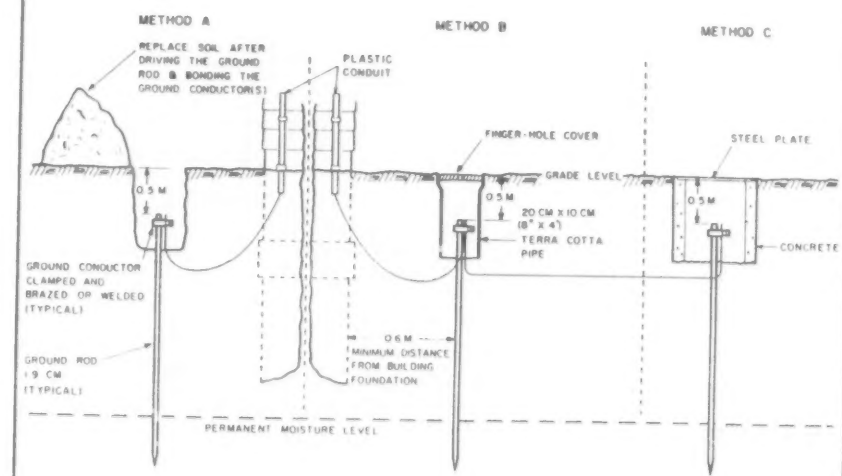
LEGEND
--- BURIED #10 BARE COPPER WIRE
○ GROUND ROD
• WELDED OR BRAZED CONNECTION

RING GROUND ELECTRODE NETWORK FOR SEVERAL BUILDINGS.

guidance **GROUNDING/1 Earth Electrode System**

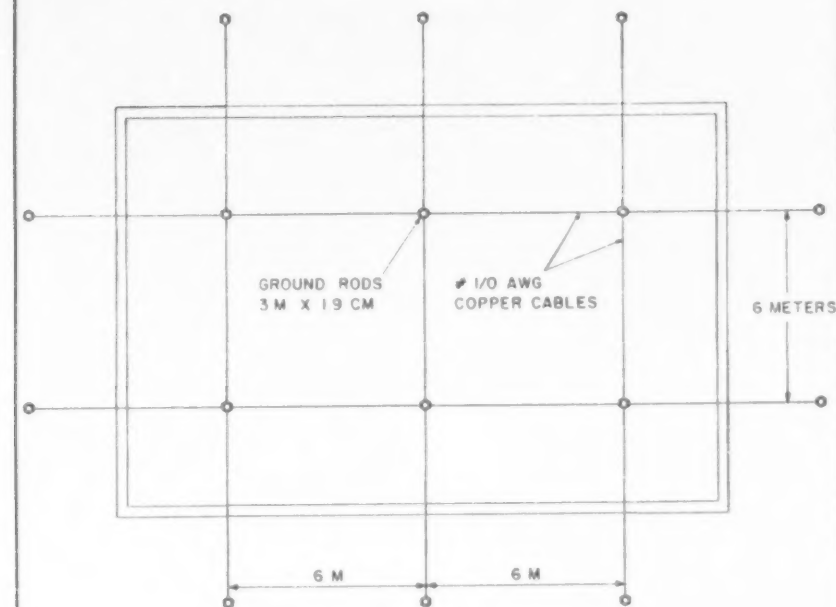
b.1. Access grounding wells for periodic checking of the interconnected ground rod system

Access to the earth electrode subsystem should be provided through the installation of at least one grounding well at each site. Either clay pipe or poured concrete may be used. Removable access covers must be provided. In very large structures, particularly those in which grounding grids are installed underneath, the grounding well or wells may be located inside the building in an accessible location. More than one grounding well may be necessary depending on the size of the facility, the extent of the electrode subsystem, and the desired degree of accessibility to the electrodes. Locate at least one of the ground wells in an area with access to open soil so that resistance checks of the earth electrode subsystem can be made once the building is in use. A ground rod installation requires connections to the signal reference subsystem, the lightning protection subsystem, and the facility ground network.



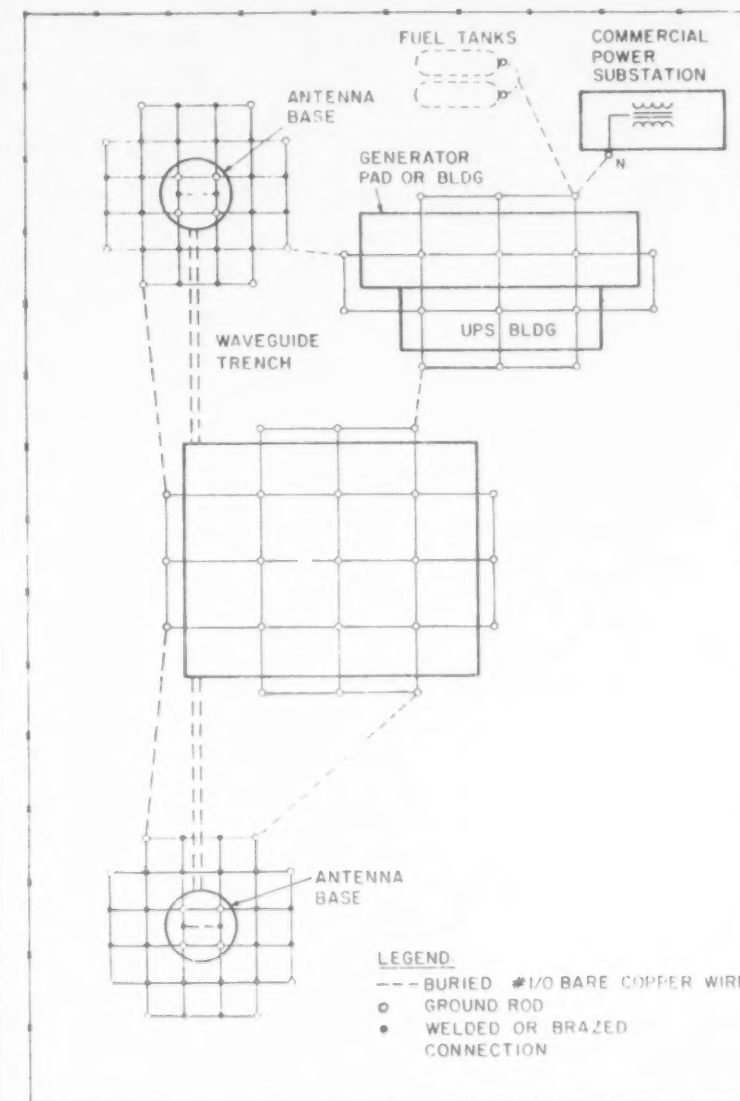
NOTE
METHODS B AND C PROVIDE READY ACCESS FOR INSPECTION, TESTING, AND MAINTENANCE LIMITED TO KEY POINTS ONLY.

TYPICAL GROUND ROD ACCESS WELL INSTALLATIONS (METHODS B AND C).

guidance **GROUNDING/1 Earth Electrode System**

NOTE:
EXTEND RADIALS FOR IMPROVEMENT
IN IMPEDANCE TO GROUND OR FOR
EQUIPOTENTIAL PLANE IN MOUNTAIN SITES.

GRID GROUND ELECTRODE LAYOUT AT A SINGLE BUILDING.

guidance **GROUNDING/1 Earth Electrode System**

GRID GROUND ELECTRODE NETWORK FOR SEVERAL BUILDINGS.

guidance **GROUNDING/2 Fault Protection System****2. Equipment fault protection subsystem composition**

One of the major shortcomings in grounding systems is the interconnection and reversal of a.c. neutral and protective wires of a.c. power distribution at various distribution panels and at equipment throughout a facility. These installation errors result in additional electrical noise and in a.c. currents in the ground system. The equipment-fault-protective subsystem should generally follow a configuration from a central or main ground point. Ideally, this configuration (if a protective wire is not available to the main ground point) should be at the primary power station transformer ground point or should be bonded directly to the earth electrode subsystem at the communications building. The configuration consists of a central main or trunk lead from the power source, with protective conductors to the various intermediate power panels and equipment. The protective wire is carried along with the phase and neutral wires from the main ground point to the main circuit breaker panel and from there to intermediate circuit breaker panels to the equipment panels. Finally, it goes to the equipment itself.

a. Ground conductor

The equipment-fault-protective subsystem, consisting primarily of the grounding conductor of the interior a.c. power distribution system, is normally a single-point network. The conductors are green insulated wires that run in the same conduit or duct with the neutral and phase conductors. The accompanying figure illustrates a typical equipment fault protective subsystem. Key points to be noted are:

1. The conduit is grounded to the power panel at each end, but it is not used instead of a ground conductor, which continues through the conduit to the protective bus bar.
2. The a.c. neutral lead can be grounded at the main a.c. entry panel. In this case, the a.c. neutral lead also serves as the protective conductor back to the source. For best results, the a.c. neutral and green wires should be grounded at the main power source for the site. This is the only point where the neutral should be grounded. (15b) 1-103

b. Exposed metallic elements of electrical equipment

1. To protect personnel from exposure to hazardous voltages, all exposed metallic elements of electrical and electronic equipment shall be connected to a ground. If inadvertent contact between the "hot" lead and chassis, frame, or cabinet occurs because of human error, insulation failure, or component failure, a good, direct, known fault current path will be established to quickly remove the hazard. Grounding a 3-phase wye power distribution system is similar to grounding a single-phase system. As in single-phase systems, the neutral lead shall be grounded for fault protection, preferably at the distribution transformer. It should never be grounded at the equipment.

guidance **GROUNDING/2 Fault Protection System**

2. Ground connections for transformers, motors, and so forth shall not be less than 1/10 AWG copper wire or the equivalent. In any case, the connections shall be rated less than the highest continuous rating of any piece of the primary apparatus that receives protection. (15b) 1-103

c. Metallic pipes and tubes

Any run of metal pipes or tubes over 3 meters (10 feet) long should be bonded to the facility ground system at each end. Bond longer runs to the facility ground system at intervals of about 45 meters (150 feet). Indoors, these bonds may be made with clamps which provide continuous pressure. Pipes installed outdoors should be bonded to the facility ground system at the entry point or, wherever feasible, by welding or brazing. (15b) 1-105

1. Metal boxes, fittings, and noncurrent-carrying metal parts of other fixed equipment do not need additional protection if they are metallically connected to the grounded cable armor or bonded to the grounded members of the building. MIL-STD-188-124 provides that the path to ground for circuits, equipment, and conductor enclosures be permanent and continuous. The path must have both the capacity to conduct safely any fault current likely to be imposed upon it, and sufficiently low impedance to limit voltage to ground and to aid the operation of circuit protective devices.
2. Section 150-91 of the NEC describes the types of materials used for equipment ground conductors, including solid wire, stranded (insulated and bare) wire, and other shapes, such as metallic tubes, pipes, and conduit. The ground conductor types permitted by the NEC also include various metal ducts, cable trays, and raceways. The NEC states that certain types of armored cable sheath may also be used as ground conductors.
3. Experience with military communication electronic facilities has shown that a low-noise, low-impedance equipment fault-protective subsystem can be maintained for a long time if separately designed and installed ground conductors are provided. Therefore, a separate equipment-fault-protective conductor shall be included with the a.c. power distribution if not included in the power cable. A green wire should be used in each case; it should be installed in the same conduit as the other a.c. wires. When ferrous ducts or conduits are used, impedance will be decreased when this independent protective conductor is installed in the same duct or conduit as the neutral and phase conductors. The impedance will be decreased even more if the protective conductor is bonded to the duct or conduit at both ends of every integral section. Where existing ducts or conduits are used and there is insufficient space for the protective conductor, it may be installed outside the conduit or duct. However, it should be bonded to the duct or conduit. In a correctly installed power distribution system, there should be no power current on the protection system.

READER
FIGURE

guidance GROUNDING/3 Lightning Protection System

tive conductor except during a fault condition. It should be noted that two types of faults cause overcurrent devices to operate. The first is an overload condition in equipment. The second fault occurs when a phase or hot lead is inadvertently grounded. In both cases, the fault current is on the neutral and phase leads. Also in both cases, the overcurrent protective device, usually a circuit breaker, is opened in the phase or hot lead. Due to the fault currents that can flow either on the phase lead, the neutral lead, or the protective conductor, it is recommended that a 2-inch separation be maintained between power runs and signal runs when neither is in a conduit.

d. Standby a.c. generators

The frames and housing of a.c. generators should be grounded as prescribed by the NEC. Ground the neutral to the facility main ground plate or to the earth electrode subsystem, whichever is closest. When generators are connected in parallel, interconnect the neutrals and ground them to the facility's earth electrode subsystem with a common grounding conductor.

3. A lightning protection system can be designed either as an integral construction component of the building or as a separate, independently mounted system. Which methods to use depends on the specific applications:

a. An integral protection system consists of air terminals interconnected with the roof and down conductors to form the shortest practicable distance to ground. When designing and installing an integral system of protection, perform the following steps: (15b) 1-23

1. Erect air terminals on the points of highest elevation and on other exposed areas to intercept the stroke before it can damage the structure or equipments or components mounted thereon. The terminal points must be placed high enough above the structure to eliminate the danger of fire from the arc.
2. Install roof and down conductors so that they offer the least possible impedance to the passage of stroke currents between the air terminals and the earth. The most direct path is the best.
3. Distribute ground connections symmetrically about the circumference of the structure rather than grouping them to one side.
4. Interconnect all metal objects close to the discharge path to prevent side flashes.
5. Make certain that the mechanical construction of the air terminal system is strong and that the materials used are highly resistant to corrosion.

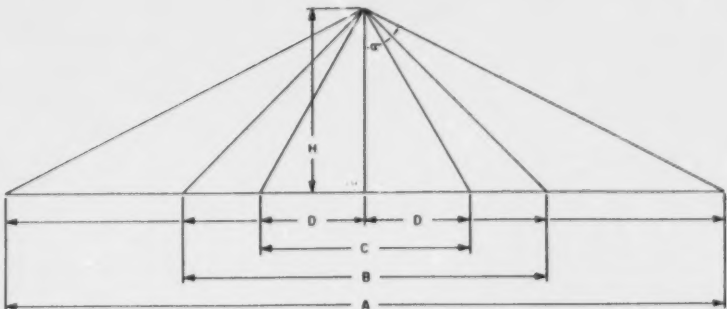
guidance GROUNDING/3 Lightning Protection System

A separately mounted protection system will be one of two types:

1. The first type of system, the mast type, consists of a metal pole which acts as both air terminal and down conductor (a nonconductive pole may be used if provided with metal air terminals and down conductors connected to an earth ground). This type of system must comply with the following guidelines: (15b) 1-40
 - No part of the structure being protected should extend outside the protected zones as calculated by the designer.
 - Where it is impractical to provide a common mast to protect an entire structure, additional masts should be provided.
 - If the pole is made of a nonconducting material, provide an air terminal extending between 0.6 meters (2 feet) and 0.9 meters (3 feet) above the top of the pole.
 - Connect the base of the mast (if metal) or the down conductors to the earth electrode subsystem of the protected structure with at least a number 6 AWG copper conductor or the equivalent.
2. The second type consists of two or more poles supporting overhead ground wires connected to an earth electrode subsystem with down leads. This type must comply with the following guidelines: (15b) 1-23
 - If the poles are of a nonconducting material, an air terminal shall be mounted securely on top of each pole. It should extend not less than 0.45 meters (1.5 feet) above the top of the pole. Down conductors are run down the side of the pole, or the guy wire may be used as the conductor. If the guy wire is used, it shall meet the requirements of paragraphs 1.3.2.2.1 of MIL-HDBK-419, and both this wire and the overhead ground wire must be dead-ended to the pole. The overhead ground wire and the guy wire shall be interconnected with a separate cable. Down conductors and guy wires used as down conductors are to be connected to the earth electrode system of the structures being protected.
 - The height of the poles should provide a clearance of not less than 1.8 meters (6 feet) between the overhead ground wire and the highest protection on the building. When the overhead ground wire system is used to protect stacks or vents which emit explosive dusts, vapors, or gases under forced draft, the cable is installed so that it has a clearance of at least 4.5 meters (15 feet) above the object being protected.

guidance **GROUNDING/3** Lightning Protection System

- With either the mast type or the overhead ground wire type of system, the pole is placed at a distance from the structure that is at least 1/3 the height of the structure. But in no case should it be placed less than 1.8 meters (6 feet) from the structure.



ZONE	D/H	α	REFERENCE	RECOMMENDED FOR
A	2/1	63°	NFPA 78	ORDINARY CASES
B	1/1	45°	NFPA 78 BRITISH CODE	ORDINARY STRUCTURES
C	0.58/1	30°	BRITISH CODE	CRITICAL STRUCTURES

LEGEND:
D/H - DISTANCE-TO-HEIGHT RATIO
α - SHIELDING ANGLE
NFPA - NATIONAL FIRE PROTECTION ASSOCIATION

COMMONLY USED LIGHTNING SHIELDING ANGLES. (1) 65

guidance **GROUNDING/3** Lightning Protection System

Air terminals and discharge path to ground

Air terminals (lightning rods) must intercept, or divert to themselves, any lightning stroke that might otherwise strike the building or structure being protected. Erect air terminals on the highest elevations and on other exposed areas to intercept the stroke before it can damage the structure, equipment, or components mounted thereon. The terminal points must be placed high enough above the structure to eliminate the danger of fire from the arc. (15b) 1-23,24

1. Size and materials of air terminals (15b) 1-24

To prevent their exploding, igniting, or otherwise being destroyed, air terminals should be made of copper, aluminum, or bronze. The minimum sizes are 1.27 centimeters (1/2 inch) in diameter for solid copper or bronze rods and 1.6 centimeters (5/8 inch) in diameter for solid aluminum rods.

- Air terminals must extend at least 25.4 centimeters (10 inches) above the object being protected. It is not enough to choose the shortest terminal which will provide this minimum height. Rather, all parts of the structure must be checked graphically or analytically in the manner described in the next section to determine if the zone of protection provided by the terminal is adequate. Where taller terminals are required to provide complete protection, adequate support and bracing as specified by ANSI-C5.1 (2.1.15) must be provided.

- Where air terminals are mounted on vents or stacks which emit potentially explosive or ignitable dusts, vapors, or gases, or very close (less than 1.5 meters, 15 feet) to the vents or stacks, provide additional clearance.

- Over hooded vents emitting explosive substance under natural drafts, the air terminals should extend at least 1.5 meters (5 feet) above the opening.

- Above open stacks emitting explosive substances under forced drafts, air terminals should extend at least 4.5 meters (15 feet) above the opening.

2. Location of air terminals (15b) 1-24

- Locate air terminals along the ridges of gable, gambrel, and hip roofs.

- Place the air terminals on the corners and along the edges of gently sloping roofs. Gently sloping roofs are defined as (1) having a span of 40 feet or less with a rise-to-run ratio, (pitch) of 1/8 or less or (2) having a span over 40 feet and a rise-to-run ratio of 1/4 or less.

guidance GROUNDING/3 Lightning Protection System

- On flat roofs, position the air terminals around the perimeter. Place additional air terminals at 50-foot intervals over the interior of flat and gently sloping roofs which are more than 50 feet in width.
 - Terminals should be provided within 2 feet of corners, the end of ridges, or edges of main roofs.
 - Terminals up to 24 inches high should be spaced 20 feet or less. Terminals taller than 24 inches may be placed at intervals not over 25 feet.
 - Insure that no part of structure extends outside the cone of protection established by the air terminals. Determine the cone of protection by preparing a simple scaled profile drawing of the structure and then superimposing a 45° (a 1:1 cone of protection) triangle on the profile. The apex of the triangle should coincide with the tip of the air terminal whose protected zone is being verified.
- b.** Low-resistance connection to the earth electrode subsystem with a low-impedance interface to earth ground
1. Joints connecting the lightning protection system with the earth electrode subsystem:
- Welded or brazed bonds are preferred over all other types. In particular, junctions in inaccessible locations should be welded or brazed whenever practical.
 - Never use soldered connections for bonding any part of the lightning protection system. Use only UL-approved connectors.
 - Where bolted connections to flat surfaces are necessary, the surface contact area should be 3 square inches or greater. (15b) 1-102

guidance GROUNDING/3 Lightning Protection System

2. Soil resistivity of various soil compositions and terrain conditions:

	Resistivity (ohm-meter)		
	Minimum	average	Maximum
Surface soils, loam, gumbo	1		5×10
Clay		2	10^2
Sand and gravel	5×10		10^3
Surface limestone	10^2		10^4
Limestone	5		4×10^3
Shale		5	$4 \times 10^{10^2}$
Sandstone (dry)	10^2		10^5
Sandstone (wet)	1		10^2
Granite, basalt, etc.		10^3	
Decomposed gneisses	5×10		5×10^2
Slate, etc.	10		10^2
Freshwater lakes		2×10^2	2×15^5
Tapwater	10		5×10
Seawater	2×10^{-1}	1	2
Pastoral, low hills, rich soil; typical of Dallas, TX, and Lincoln, NE, areas		3×10	
Flat country, marshy, densely wooded; typical of Louisiana near Mississippi River	2	10^2	
Pastoral, medium hills and forestation; typical of Maryland, Pennsylvania, and New York, except for mountainous territory and seacoasts		2×10^2	
Rocky soil, steep hills; typical of New England	10	5×10^2	10^3
Sandy, dry, flat; typical of coastal country	3×10^2	5×10^2	5×10^3
City, industrial areas		10^3	10^4
Fills--ashes, cinders, brine wastes	6	2.5×10	7×10
Clay, shale, gumbo, loam mixture	3	4×10	2×10^2
Same as above, with varying proportion of sand and gravel	10	1.5×10^2	10^3
Gravel, sand, stones, with little clay or loam; granite	5×10^2	10^3	10^4

guidance GROUNDING/3 Lightning Protection System

c. Lightning-generated transient surge protection (15b) 1-52

Electrical and electronic equipment at various installations has been damaged severely by lightning-generated transients. The transients occur on externally exposed lines that directly interface equipment. Externally exposed lines are outside lines, buried lines, overhead lines, and so forth that are exposed to weather elements. The lines include incoming a.c. service conductors, and equipment signal, status, control and intrafacility a.c. and d.c. power lines. This section identifies methods that will prevent equipment damage and operational upset when transients occur.

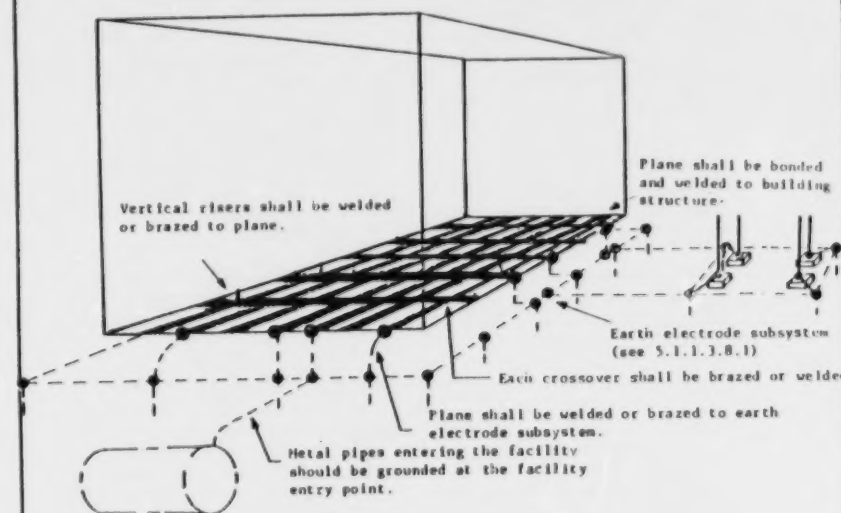
1. Damage can be minimized, and in most instances eliminated, by proper use of the protection methods detailed in this section, most of which are proven in the field. In order to be cost effective and to provide effective protection, protection must be divided into three general categories:

- Transient suppression devices (metal conduit and guard wires) on outside lines that interface equipment to be protected.
- Transient suppression devices on both ends of exterior lines immediately after they enter the equipment building or at the termination of exterior equipment, and on incoming a.c. service entrance lines at the facility's main service disconnections.
- Transient suppression devices as an integral part of protected equipment at the exterior line-equipment interfaces.

2. If transient protection is to be designed realistically, it is necessary to define frequency of transient occurrence, amplitudes, and waveforms or transients, as well as the withstand level of protected equipment. The withstand level is the short-duration voltage and current surge levels that equipment can withstand without overstressing or immediate destruction of components occurring, and without operational upset of the equipment. The information required for effective protection is given in MIL-HDBK-419, which identifies the most susceptible components and typical withstand levels. MIL-HDBK-419 also gives the frequency of transient occurrence. The large physical size of incoming a.c. service conductors presents less impedance (resistance and inductance) to transient surge current flow. As a result, amplitude and waveforms of transients appearing at a.c. inputs are quite different from those appearing at control, status, data, signal, and in-system powerline inputs. Therefore, protection for incoming a.c. power service conductors is discussed separately from protection for other externally exposed lines. (15b) 1-52

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4. a. Signal reference systems for higher frequencies are based upon the utilization of an equipotential ground plan (see the following diagram).



EXAMPLE OF EQUIPOTENTIAL PLANE FOR NEW CONSTRUCTION.

1. Equipotential plane for the higher frequency signal reference network as a multipoint ground system (15b) 1-118

The multipoint ground system requires an equipotential ground plane. Such a plane exists in a building with a metal floor or ceiling grid electrically bonded together, or a concrete floor with a ground grid embedded in it, connected to the facility ground. Equipment cabinets are then connected to the equipotential plane. Chassis are connected to the equipment cabinets and all components, signal return leads, and so forth, are connected to the chassis. The equipotential plane is then terminated to the earth electrode subsystem. This assures personnel safety and a low impedance path for lower frequency signals.

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At higher frequencies, the large conducting surface, embedded in the floor or in the metallic raised floor under the pieces of equipment to be grounded, presents a much lower characteristic impedance than a signal wire (even if both were terminated improperly). This is true because the characteristic impedance (Z_0) is a function of L/C. As capacity to earth increases, Z_0 decreases. Normally, the capacity of a metallic sheet to earth is higher than that of wire. If the size of the sheet is increased, thus encompassing more area, the capacitance increases. Also, the unit length inductance decreases with width, further decreasing Z_0 . If the dimensions of a metallic sheet increase extensively (as in the case of a conducting subfloor), the characteristic impedance becomes very low. In this case, even if terminated improperly, the impedance would be quite low in much of the spectrum. This, in turn, would establish an equipotential reference plane for all equipments bonded to the impedance.

Equipotential planes can be created using many construction materials. The following four items are typical for any equipotential plane that can be used as a multipoint ground system: (15b) 1-118

- o In steel frame buildings, make all structural members of the building (such as building columns, wall frames, and roof trusses) electrically continuous by bonding each joint and interconnecting with a welded, brazed, soldered, or high-compression bolted connection. Where direct bonds of these types are not possible, bridge the joint with a 1/0 AWG stranded copper cable, both ends of which are brazed, welded, or bolted in place. This does not include rebars.
- Connect the bonded structural steel network to the earth electrode subsystem with 1/0 AWG copper cables. The distance between adjacent connections from the building structure to the earth electrode subsystem should not exceed 15 meters (50 feet).
- Where steel frame construction is not used, install a supplemental network consisting of large copper cables, in accordance with the following table.
- Equipment cabinets, electrical supporting structures, and utility pipes are to be connected to this structural steel or copper cable grid (equipotential plane) with cables providing at least number 6 AWG copper wire. (Electrical supporting structures include all the conduits, raceways, switch and breaker panels, and other hardware (not energized) usually associated with communications facilities).

The more extensive the equipotential ground plane, the more effective it is in minimizing differences in potential between interconnected equipment at higher frequencies.

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SIZE OF EQUIPMENT GROUND CABLES FOR VARIOUS LENGTHS

Maximum path length (feet)	Cable size (AWG)	Busbar (inches)	Maximum path length (feet)
375	750 MCM	4 x 1/4	636
300	600 MCM	4 x 1/8	318
250	500 MCM	3 x 1/4	476
175	350 MCM	3 x 1/8	238
150	300 MCM	2 x 1/4	318
125	250 MCM	2 x 1/8	159
105	4/0	2 x 1/16	79
84	3/0	1 x 1/4	159
66	2/0	1 x 1/8	79
53	1/0	1 x 1/16	39
41	1		
33	2		
21	4		
13	6		
8	8		

2. Types of equipotential planes (15b) 1-120

Conducting media that can be utilized for the equipotential plane are (1) a copper grid embedded in the concrete floor or raised metal floor (such as a computer facility floor), (2) a raised floor, (3) a subfloor of aluminum, copper, or sheet metal laid underneath the floor tile, and (4) a ceiling grid above the equipment.

Copper grid embedded in concrete--If a large conducting surface is not economically feasible, the designer should consider a ground reference plane, made up of a copper grid. Copper grids with silver grazed grounds are commercially available. They are obtainable in mesh spacings of from 5- to 61-centimeter (2- to 24-inch) squares, in AWG wire sizes numbers 6, 8, 10, and 12. These grids are usually furnished in 3.7 meter- (12-foot) rolls, but can be obtained in various widths up to 5.5 meters (18 feet). Ground connections can be made to the grid by direct bonding or manufactured ground "buses" that are connected to the grid and give grounding access at the floor surface. If the grid is embedded in a concrete floor, the latter method usually gives the easiest grounding source. The equipotential plane shall be welded to the main structural steel of the building at multiple locations. Where frame buildings are utilized, the plane is connected to the earth electrode subsystem at multiple locations using 1/0 copper conductors.

Metallic subfloor under wearing surface--An equipotential plane can be achieved by installing a solid metal sheet or

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roll of either aluminum or copper under the floor tile or carpet of the equipment rooms. The plane shall be welded to the main structural steel members of the building at multiple locations. The structural steel shall in turn be welded to the earth electrode subsystem. A somewhat more economical method would be to form a grid of 2 to 3-inch strips of copper brazed at all crossovers with squares not over 2 feet on each side. The resulting grid will be welded to the main structural steel. Where steel frame and concrete construction is not used, install a supplemental network consisting of large copper cables. This method is not considered as acceptable as the techniques described here. It should only be used after other techniques are considered.

Ceiling grid above electronic equipment--An overhead equipotential grid system consisting of wall members (1/0 AWG yellow-covered stranded cable) around the inner perimeter of the equipment room and cross members (2/0 AWG yellow-covered stranded cable) above the equipment rows can also be employed as an equipotential plane. 1/0 AWG cable can be used to connect the equipotential plane to an earth electrode subsystem, while 2/0 AWG cable can be used to connect the equipment to the cross member.

Raised floor system--Raised floors are used to structurally support equipment cabinets and provide a space between the original facility floor and raised floor plates and cabling, air plenum or air-conditioning ducting, piping, drains, and so on. Raised floors improve the appearance of rooms. Three general types of floor systems manufactured are: (1) the bolted-grid (stringer), or rigid grid system, (2) the drop-in grid, or removable grid type, and (3) the free-standing, stringerless, or pedestal-only type.

Bolted-grid (stringer) or rigid grid system--Shown in the following figures are bolted-grid floor systems. The systems are similar to the drop-in grid except the grids, when properly installed, are securely bolted or clamped in place. Floor panels are normally 24 by 24 inches as in the removable grid system. The individual grid lengths may vary. Some manufacturers use "main" stringers that span three pedestals (approximately 6 feet) whereas the "cross" stringers are less than 2 inches (for the 24 by 24 inch floor panel). Materials used for stringers and pedestal heads are steel and aluminum. Standard floor panels are steel or aluminum with a selected floor covering. Raised flooring to be used for equipotential plane should be purchased to conform to the requirements of MIL-F-29046 (TP) 30 September 1975. In general, the grounding aspects of raised flooring have been excellent. Problem areas that designers should be aware of are:

- Installation practices (15b) 1-125: Inadequate bonded joints between pedestal heads and stringers have sometimes resulted from poor installation practices primarily through

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- (a) pedestal heads heavily oxidized and dirty when bolted,
- (b) use of poor bolting hardware (speed nuts, sheet metal screws), or (c) bolting hardware not installed or not tightened properly.

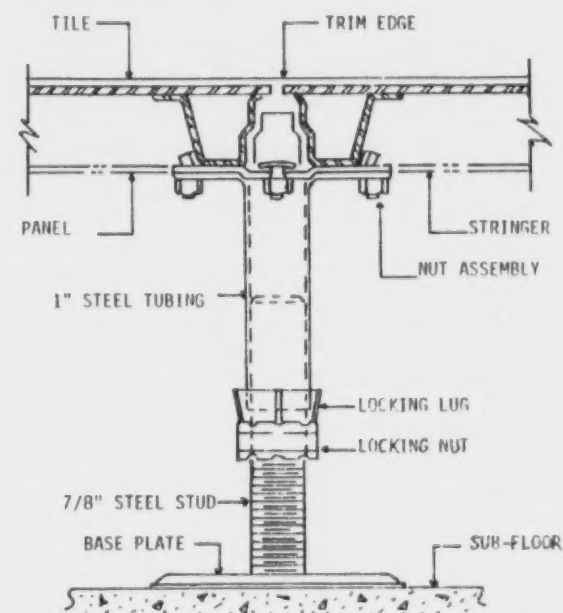
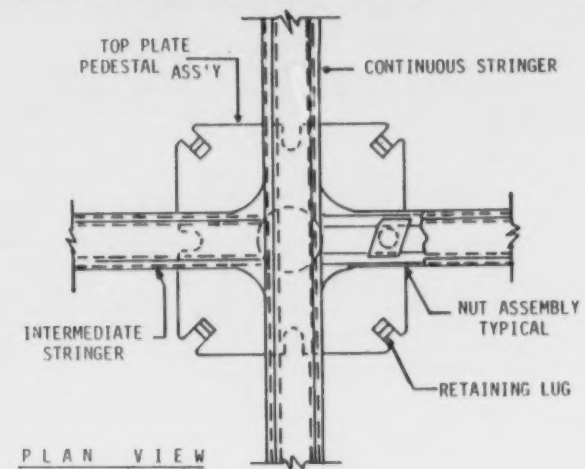
Clipnuts shall not be used in place of standard nuts since they usually will deform, producing loose joints.

The installer may receive heavily oxidized aluminum pedestal heads from the manufacturing plant. The joint surface requires minor abrasion and perhaps a light coating of a joint protective compound. The joint compound should be particularly considered for noncarpeted floors when moisture, cleaning compounds, and wax would settle, degrading the joint (sometimes severely) over several years.

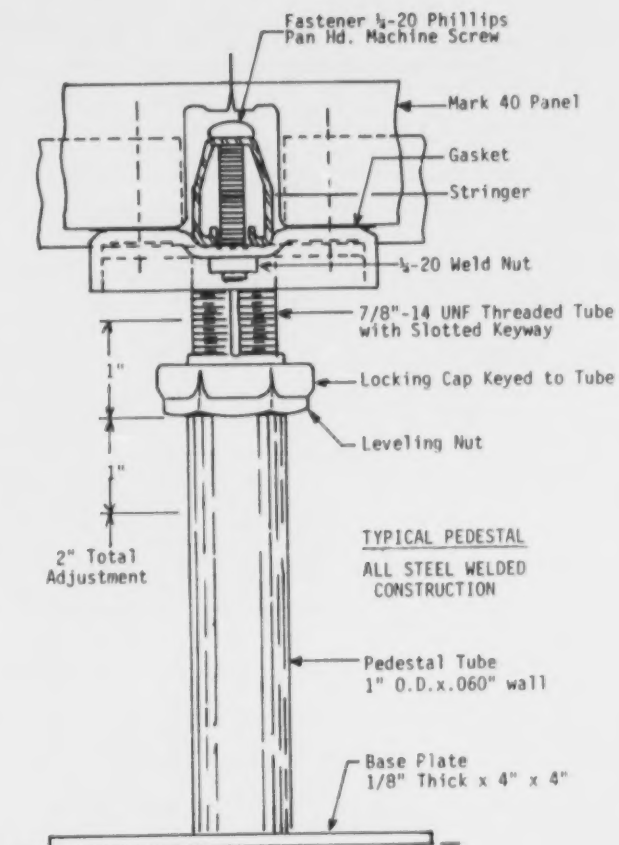
Improper bolting hardware can produce unreliable joints. All bolted bonds must meet the requirements of Table 1-23, MIL-HDBK-419. Sheet metal screws have sometimes been used to support the stringer to the pedestal. Clipnuts used instead of standard nuts will deform and produce loose joints, and shall not be used. This "clip" nut, called the "grip lock nut," is shown below in the example of unacceptable grid-to-pedestal bonding. MIL-F-29046 has been modified to specifically prohibit the use of such hardware.

It is recommended that the installation crew be briefed and the floor tested before the floor panels are installed.

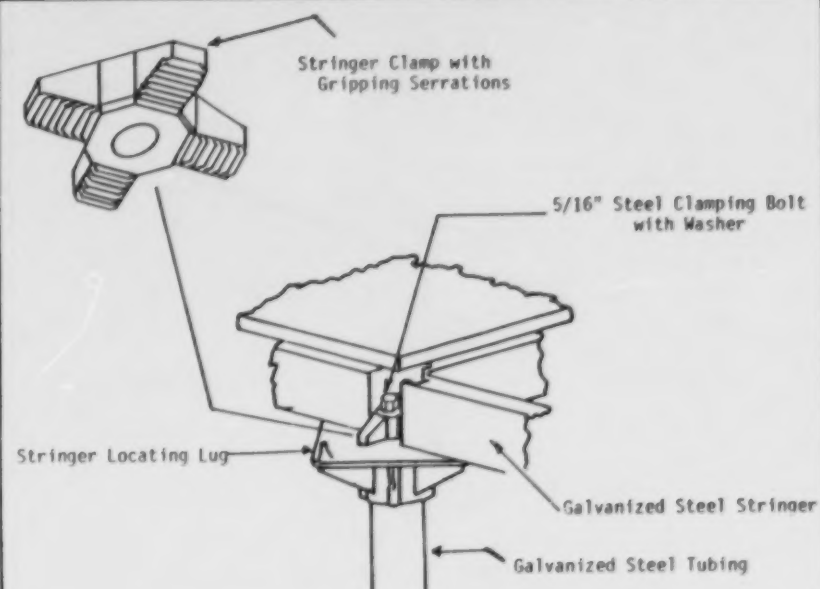
- Floor system checkout: Composite bonds between cabinet chassis and the raised floor shall not exceed a specified resistance value, usually 1 milliohm. Typically, a pedestal head-to-stringer resistance will read about 40 micro-ohms and should not exceed 100 micro-ohms. For additional information see MIL-F-29046.
- Resistance measurement equipment: The instrument recommended to obtain resistance used for measurements is a modified Shallcross Model 670A Milliohmmeter.

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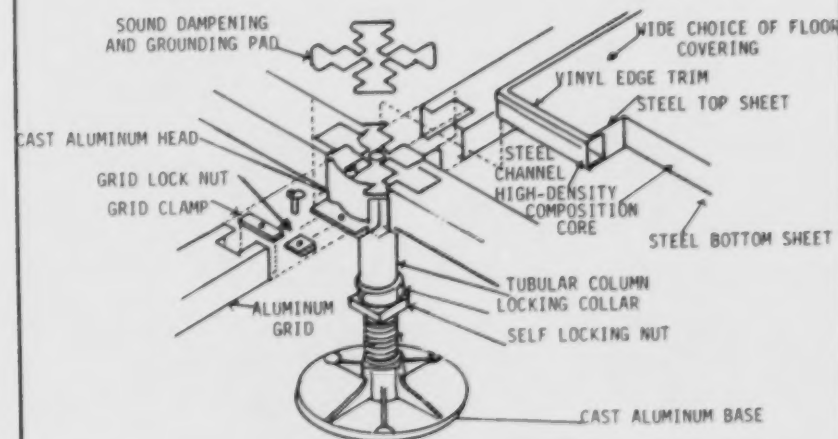
RIGID GRID FLOOR SYSTEM DETAILS.

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EXAMPLE OF RIGID-GRID-TO-PEDESTAL BOLTED CONNECTION.

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EXAMPLE OF RIGID-GRID-TO-PEDESTAL CLAMPED CONNECTION.



EXAMPLES OF UNACCEPTABLE GRID-TO-PEDESTAL BONDING.

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- **Connections to the raised floor system:** Connections from the equipment racks and the earth electrode subsystem to the floor are important. Clamps, if used, should be installed on the upper pedestal assembly to avoid the relatively high resistance between the lower assembly (that has the base) and the upper column. The stringer to pedestal fastener hardware often can be changed to allow bolting a bonding cable terminal directly to the pedestal head. It is feasible to obtain additional grid locking hardware and use it to bolt the bonding cable terminal to the floor grid. Another way to terminate a bonding cable is to drill a hole and bolt it to a nonheavy weight bearing stringer.
- **Corrosion control:** In extremely humid environments at which corrosion is common, corrosion prevention compounds are recommended. Bolted joints can be covered with a non-corrosive silicone-rubber compound that will protect the joint for the installation's life. The silicone-rubber can be smoothed by rubbing an ice cube over it.
- **Carpeting:** Carpeting selected as a floor covering should be of a low-static or static-free type to prevent possible static discharge or component failure. See MIL-F-29046 for additional information.
- **Maintenance measurements:** To determine floor degradation, resistance measurements and method should be documented and available so that repeat measurements can be made if ground reference subsystem problems are suspected or so that degradation can be checked for periodically.
- **Reliability:** The MIL-F-29046 specification provides information for raised floor procurements. The guidelines in this handbook will provide a ground reference subsystem that is well designed, installed properly, and expected to last for the life of the electronic system installation.

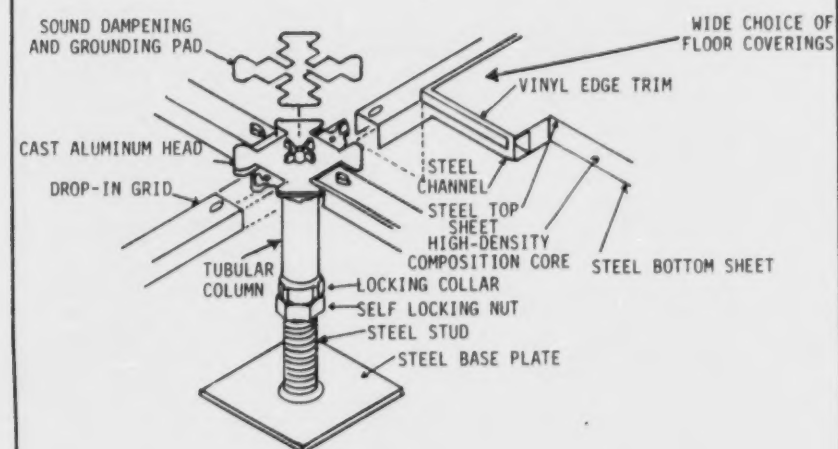
Drop-in or removable grid system--The figure below shows the drop-in-grid system. The grids or stringers are retained by engaging pins or depressions in the pedestal head. The stringers give support and, when newly installed, provide comparatively low-resistance contact to the pedestal head. Equipment cabinets resting on the floor panels provide increased contact pressure in certain areas. However, severe corrosion and unreliable electrical contact have resulted due to dirt, moisture, and floor cleaning/waxing compounds filtering through crevices. This floor system is considered unsuitable for a reference plane. Floor panels resting on the pedestals and grids are commonly 24 by 24 inches, although they can be purchased in 30 by 30 inch dimension.

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Free-standing, pedestal-only or stringerless system--In the pedestal-only system (see figure), the pedestal base is glued or "shot" in place to form the basic understructure. The pedestal heads are leveled and the floor panel is installed. The conductivity between distant pedestals is variable and unreliable, making it unsuitable for a ground reference.

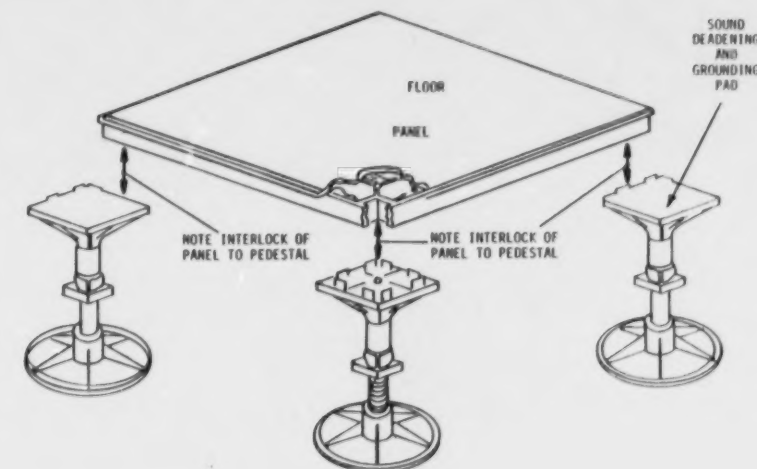
Ground risers--The type of ground riser to be used depends on the type of equipotential plane to be installed and whether the subject building will be new construction, a major modification to an existing building in which new equipment will be installed, or an existing building in which only the ground system will be upgraded while the equipment remains in place.

Equipment cabinet grounding--Each individual unit or piece of equipment should either be bonded to its rack or cabinet (see figure), or have its case or chassis bonded to the nearest point on the equipotential plane. Racks and cabinets should also be bonded to the nearest point of the plane.

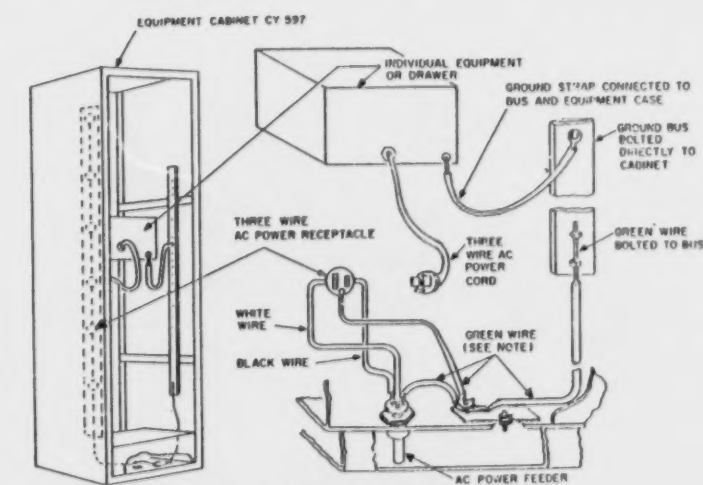


EXAMPLE OF DROP-IN GRID FLOOR CONSTRUCTION.

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EXAMPLE OF PEDESTAL-ONLY FLOOR CONSTRUCTION.



TYPICAL EQUIPMENT CABINET GROUNDING DETAIL.

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- b.** Signal reference systems for lower frequencies are based upon the utilization of a main ground plate.

Signal grounding network

Configure the lower frequency (below 300 kilohertz), in some cases below 30 kilohertz, grounding network for a facility as an isolated tree. It is essential that the signal grounding networks in a facility be designed and installed in a way that controls interference coupling. Not all circuit and system noise problems will be solved, even with correctly designed networks (either lower frequency or higher frequency). Additional measures such as reducing the levels of the sources of interference through shielding, filtering, or alternative design; using common-mode rejection techniques; and implementing various other coupling control techniques frequently will be necessary to limit the noise level in system circuits to a noninterfering level. The following steps are needed for a typical lower frequency reference network:

- Install a main ground plate at a central location in the facility to provide a single point of interconnection between the lower frequency ground network, the facility ground system, and the power system ground.
- Install a trunk ground cable between the main ground plate and branch ground plates located throughout the facility.
- Provide branch ground cables extending from the branch ground plates to the feeder ground plates located in rooms or areas near equipment.
- Connect the signal reference points or planes within each piece of equipment to the feeder ground plates with insulated conductors.
- Adapt the network to meet the facility's needs. If the facility is large and complex with lower frequency equipment distributed throughout, then the network should be configured to each into all pertinent areas. On the other hand, if the lower frequency equipment is located in one specific, limited area, it is necessary to extend the network only into that area. Similarly, a small facility with no lower frequency equipment installed inside would not require such a network.

1. Main ground plate

The main ground plate shall be copper. Copper is preferred because it resists corrosion in the presence of other metals. Securely mount this plate in a readily accessible location.

2. Trunk ground cable

- Route the insulated trunk ground cable from the main ground plate to equipment locations to minimize conductor length.

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- Avoid long runs in parallel with unshielded power cables and locate as far as possible from lightning down conductors. Where close routing with power lines cannot be avoided, either the power line or the main ground cable should be placed in an iron or steel conduit.

- Conductor sizes for the signal ground cables should be no smaller than number 2. They should be based on providing a cross-sectional area of 500 circular mils per running foot of conductor.

Minimum wire cross section (in circular mils) = length of run in feet x 500 circular mils per foot.

This criterion limits the d.c. resistance between any two points on the network to 20 milliohms.

- The minimum size recommended for the trunk ground cable is 1/0 AWG. For short lengths, a 1/0 cable will provide more than 500 circular mils per foot. For example, assume a run length of 50 feet. The minimum cross sectional area for the conductor should be 50 x 500, or 25,000 circular mils. The smallest standard AWG cable meeting the requirement is number 6 (26,250 circular mils). However, because of the extra mechanical strength and the lower resistance offered by the larger 1/0 cable, it is recommended over the smaller cable. Further, by initially installing a large cable, future expansions and modifications can be made in accordance with the 500 circular mil criterion without a change in cable size.

- Limit the total length of the trunk ground to not more than 60 meters (200 feet). If longer lengths are required, install a larger cable or provide duplicate networks within the facility. In structures of large lateral dimensions where equipments are widely separated and one 200-foot cable will not suffice, parallel networks are recommended. In tall structures where equipment is distributed vertically, an increase in cable size is preferable.

3. Branch ground plate

- Install a branch ground plate on each floor or in each major area containing lower frequency equipment. This plate will provide a convenient point for interconnecting the trunk ground cable with the branch ground cables.
- To maintain the isolation of the network, the plate must be mounted on insulated standoffs, with insulating washers, or fastened with nonconductive screws.

guidance GROUNDING/4 Signal Reference System**4. Branch ground cable**

- Install branch ground cables to provide the extensions needed between the main trunk cable and the general equipment areas. These cables must be at least number 2 AWG in size. In accordance with the 500 circular mil per foot criterion, do not permit the total length between the branch ground plate and the feeder ground plate (see the following section) located near the equipment to exceed 150 running feet (45 meters).
- In facilities where feeder cables longer than 45 meters (150 feet) would be required to reach equipment locations, install separate lower frequency grounding networks. Do not simply run longer equipment signal grounding conductors from the equipment to the feeder ground plates.

5. Feeder ground plates

- Locate feeder ground plates near equipment that uses them. The ground plates should be attached securely to the signal ground cables from individual equipment items and branch ground cables with bolts and lockwashers.
- The plates should be made of copper with dimensions of 15.3 x 10 x 0.6 centimeters (6 x 4 x 0.25 inches).
- Use insulating posts, insulating washers, or nonconductive screws for mounting to maintain network isolation from the facility ground system.

Multiple networks

When multiple networks are installed, electrical isolation must be maintained between them except at the interconnection at the main ground plate (if one plate serves two or more networks) or through the earth electrode subsystem (if separate ground plates are used for each network). Branch ground cables from two separate grounding networks should not be attached to the same feeder or branch ground plate. Inadvertent interconnections through equipment must also be avoided.

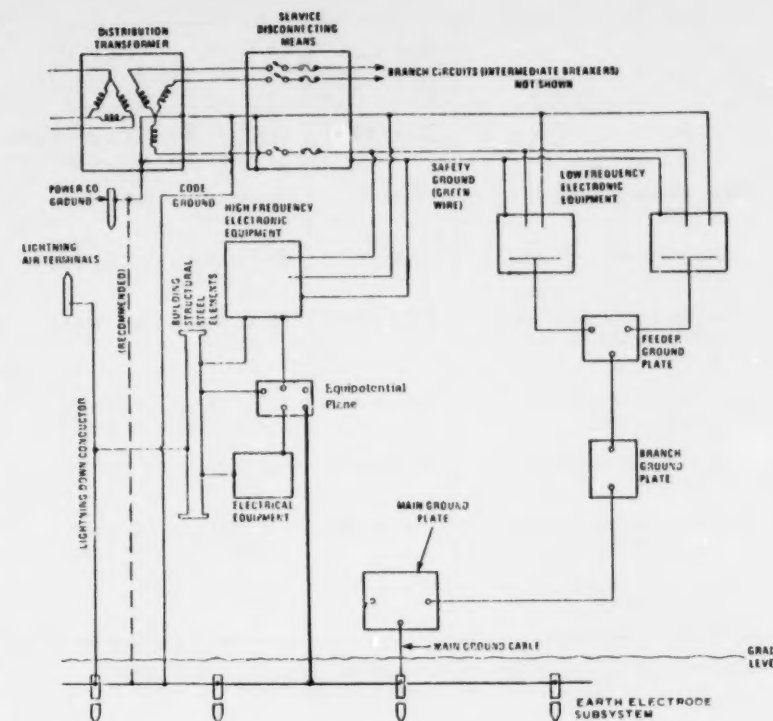
After installation, but before interconnections with equipment are made, check the isolation between separate grounding networks with an ohmmeter (with one of the networks disconnected from the main ground plate). At least 1 megohm should be registered between networks.

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- C.** The hybrid frequency signal network is the presence of a combination of both higher and lower frequencies. Where required, an isolated, single-point signal grounding network will be provided for lower frequency equipment. Higher frequency equipment is grounded to the equipotential plane. (15b) 1-41

The figure below shows recommended grounding practices for a typical electronic facility. Representative lightning, power, safety, and signal grounds for both lower and higher frequency equipment are shown. (This figure should be interpreted only as showing how the various ground networks interface. Every grounding situation is not shown.)

1. The neutral of the transformer's wye-connected secondary is grounded to the transformer case and to the power company's ground or grid. This transformer ground connection can be provided by the facility's earth electrode subsystem instead. It is recommended that the transformer ground be interconnected with the structure ground when feasible. (This recommended interconnection is shown as a dashed line on the figure.)
2. The neutral is connected to the facility earth electrode subsystem as required by the NEC. The neutral is grounded on the input side of the service disconnect but at no other point, even inside equipment. All equipment cases are grounded through the NEC's "green wire" or safety ground. All exterior parts of electrical and electronic equipment exposed to human contact are grounded in this way.
3. When required, an isolated, single-point signal grounding network will be provided for lower frequency equipment. This tree network extends throughout the facility as needed. Higher frequency equipment is grounded to the equipotential plane. Equipment fault protection is provided by equipment grounding cables interconnected through equipment ground plates. Structural elements are grounded to the earth electrode subsystem. (The main ground plate serves as a central tie point between the lower frequency grounding network and the earth electrode subsystem.)
4. The lightning protection subsystem is grounded to the earth electrode subsystem for the structure. Cross bonding between roof and down conductors and structural elements is provided for spacings of 6 feet or less.

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COMBINED HIGH/LOW FREQUENCY SIGNAL REFERENCE FACILITY.

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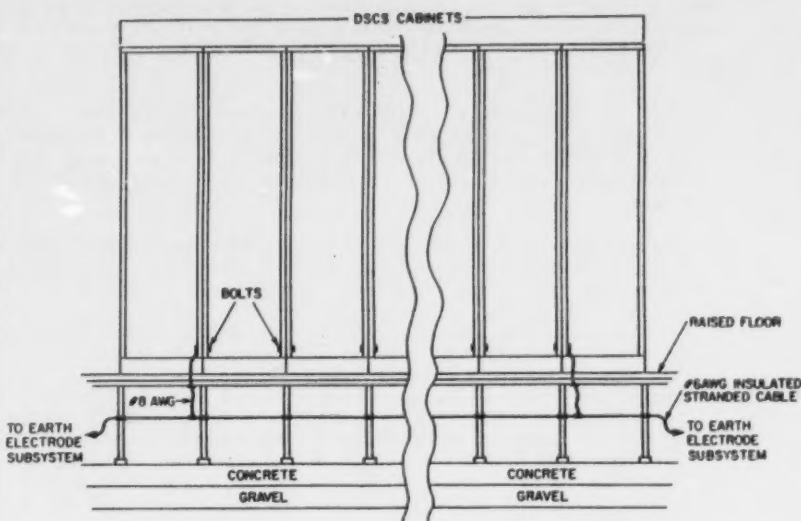
d. For crypto gear, the red signal reference subsystem consists of an equipotential plane which is isolated from the building ground and from the black equipotential plane. The following exceptions apply:

1. The red equipotential plane will be connected to the black equipotential plane at only one point. This connection should be located as near to the crypto equipment as practicable, and the crypto case should be connected to the red equipotential plane.
2. The red and black planes are also tied together inadvertently through the green (grounding) wire of the fault protection subsystem.

When a red facility is located in a commercial building or otherwise uncontrolled area, a separated down lead will be installed from the red equipotential plane to the earth electrode subsystem. This down lead will not be run in a small metallic conduit but must be protected by other means, such as a plastic conduit or metallic duct large enough so it does not act as a waveguide filter. This down lead is not required for buildings totally within a controlled zone. Under those conditions, the red and black signal reference subsystem can be one and the same equipotential plane via a ground strap by the shortest route possible. In most cases, these bond straps will not be more than 8 inches long. They should be thin enough to allow some flexibility, but braided straps shall never be used.

3. The red signal reference system may be established in any of the following ways:
 - A wire mesh embedded in or on top of a concrete floor.
 - Floor, where it exists.
 - Raised flooring in accordance with MIL-F-29046(TP) 30 Sep 75.
 - The metal underlayment of a Robinson-type floor.
 - Overhead wire mesh installed on or near the ceiling.
 - Wall and cross-member grid on or near the ceiling. (15b) 1-142
4. Red data equipment grounds must be made so as to preclude ground loops.

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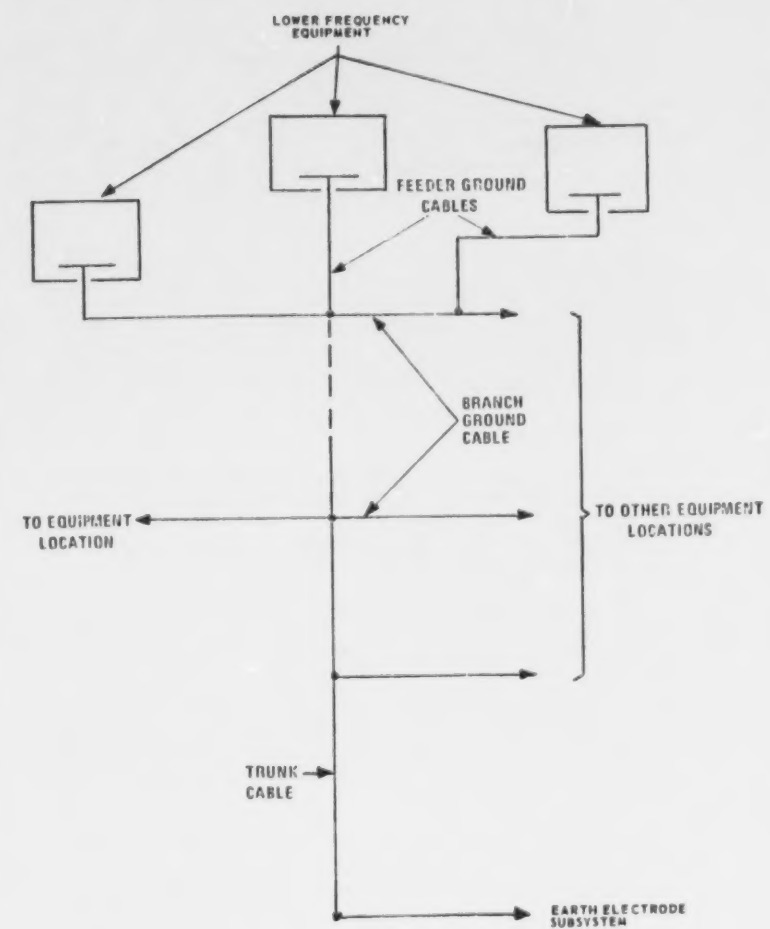
EQUIPOTENTIAL SIGNAL REFERENCE NETWORK FOR EXISTING INSTALLATIONS (DSCS). (1) 73

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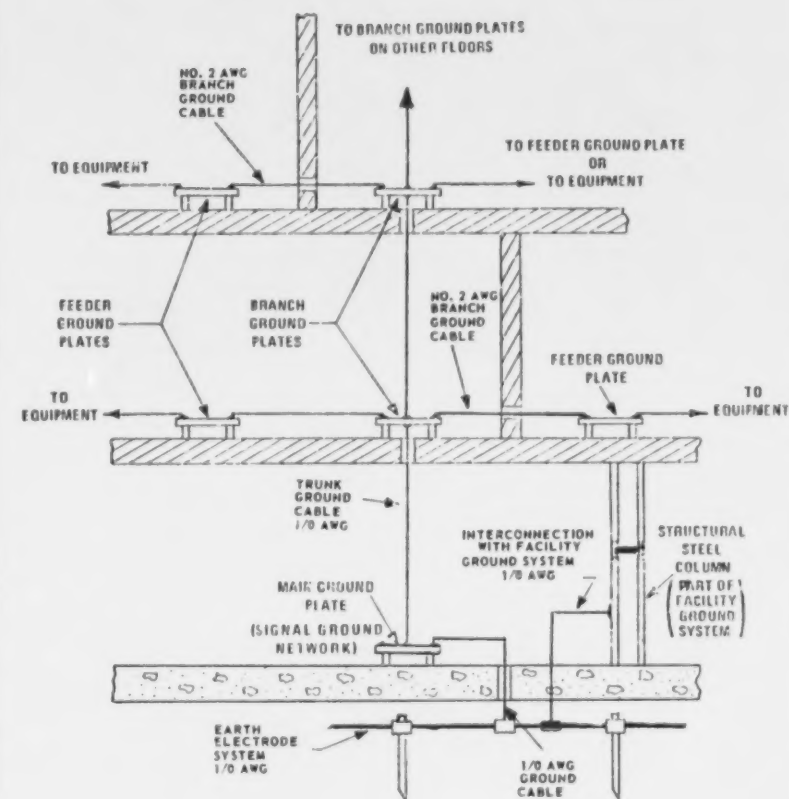
Application	Wire size range (AWG)	Typical recommended
Ring ground to inside ground grid	#2 to #4/0	#1/0 solid or coarse-stranded wire, insulated, yellow*
Main inside ground wires (ring)	#4 to #2/0	#2 stranded, insulated, yellow
Spurs from main ground wires (grid)	#6 to #4	#6 stranded, insulated, yellow
Downleads from main inside ground wires to cabinets or racks	#10 to #6	#8 stranded, insulated, yellow
Inside cabinet or rack ground wires	#18 to #10	#12 solid or stranded, insulated, yellow
Combined CDF ground wire harness	#14 to #10	#12 solid, insulated, yellow
Ground wires to terminal blocks on CDF	#18 to #12	#18 solid or stranded, insulated, yellow
Ground pin straps on terminal blocks	#22 to #20	#22 solid, bare

*Protected by plastic conduit on exterior exposed walls and bare .6 meters (2 feet) below the surface of the soil.

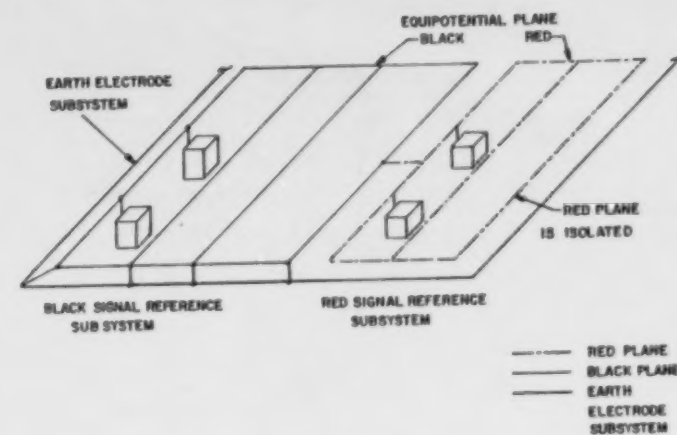
WIRE TYPES AND SIZES FOR SIGNAL REFERENCE APPLICATIONS (1) 74

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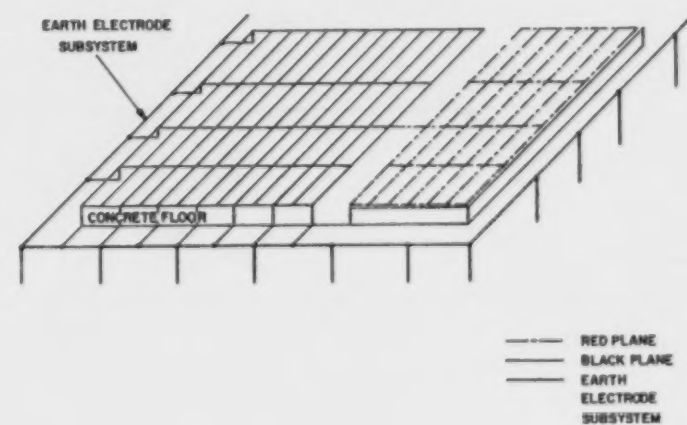
SCHEMATIC OF THE LOWER FREQUENCY SIGNAL GROUND NETWORK.

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TYPICAL LOWER FREQUENCY SIGNAL REFERENCE NETWORK INSTALLATION.

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OVERHEAD RED/BLACK SIGNAL REFERENCE SYSTEM.



RED/BLACK SIGNAL REFERENCE SUBSYSTEM ON CONCRETE FLOOR.

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Wire mesh, when used, shall have openings no larger than 1/50 g at the highest frequency of concern. Copperclad steel or dead soft copper wire meshes with brazed crossover are commercially available in mesh spacings from 2- to 24-inch squares in AWG wire size Nos. 6, 8, 10, and 12. It is normally furnished in 12 feet but can be obtained in various widths up to 18 feet. Wall or crossmembers shall be yellow insulated, 1/0 or 2/0 19-strand copper cables. See figure. (15b) 1-147

Power distribution--The red a.c. distribution system is totally enclosed by equipment cases, cabinet racks, duct, conduit (rigid, EMT, flexible) metallic cellular floors, technical power panels, main power panels, etc., all connected or interconnected in such a way that the components are electrically common and connected to the fault protection subsystem at the first disconnect means. This will provide a degree of shielding for the red power distribution system. The green wire will be bonded to each of the above components.

Red and black signal cables shall as a minimum have an overall shield terminated at both ends to equipment cases, distribution frame ground buses, or equipment cabinets/racks as the case may be. These are bonded to their respective red or black equipotential planes. (15b) 1-147

Grounding precautions--To the extent possible, inadvertent contact of the red equipotential plane to fortuitous conductors in the walls or floors which do not have an adjacent controlled access area (CAA) should be avoided when installing the red signal reference subsystem. Moreover, insulators should not be used unless specifically required, and then only on a case-by-case basis. All components of the red signal reference subsystems should be contained within the CAA or the controlled space (CS) as defined in NACSIM 5203(c). (15b) 1-147

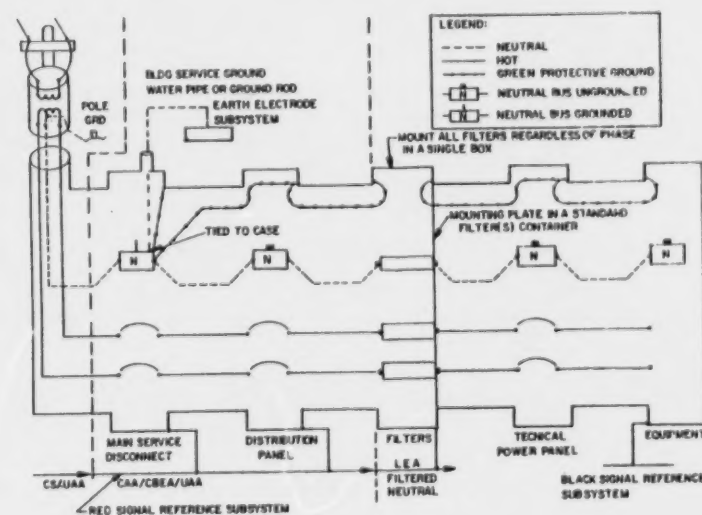
Filter grounds--To minimize the degradation of filter insertion-loss characteristics due to varying impedances between filter cases and the earth electrode subsystem, filter cases should be bonded either to equipment cases or directly to the red signal reference subsystem. It is recommended that, in this case, the filter input use shielded cable and that the shield be connected to the filter case through the connector shell (not through a pigtail). (15b) 1-147

Earth electrode subsystems--The earth electrode subsystem design should conform to the criteria previously stated in this guide. All subsystems of a given facility are bonded to the earth electrode subsystem. All underground metal objects such as water pipes, well casings, and fuel tanks shall also be bonded to this common subsystem and should never be depended on to provide a reliable earth connection. (15b) 1-147

guidance GROUNDING/4 Signal Reference System

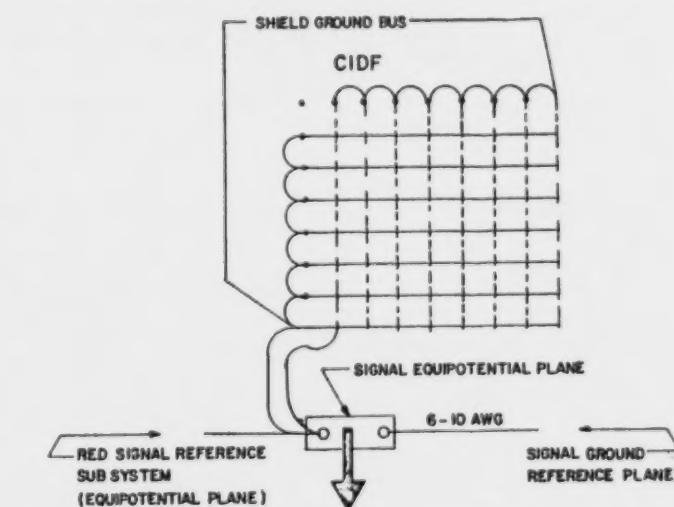
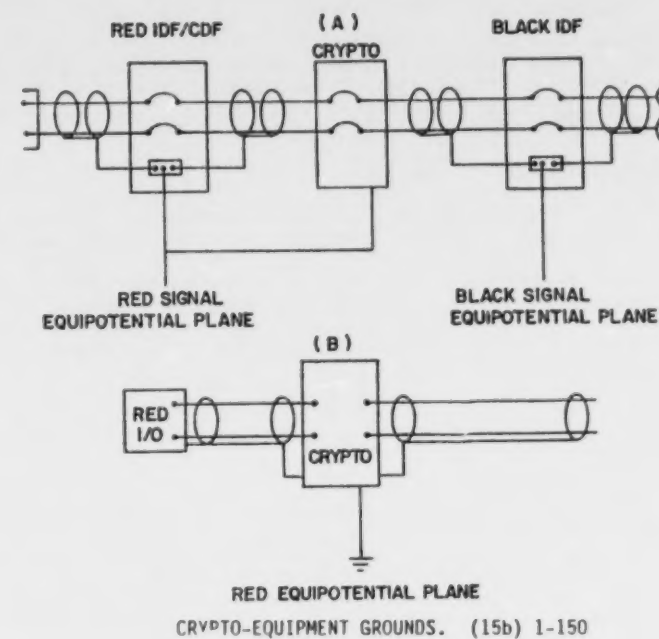
In large facilities, several controlled access red areas may require multiple red signal reference subsystems. Each of these may be connected to the black signal reference subsystem at one point only. These connections should be made at nearest point by the shortest practical route. See the figure. When these connections must pass through uncontrolled areas, they shall be protected by plastic conduit or 4-inch square metal duct. (15b) 1-147

Signal ground bus--A ground bus found in the Main Distribution Frame (MDF), Intermediate Distribution Frame (IDF), and Classified Intermediate Frame (CIDF) serves as the ground system connection point for the nonferrous shields of the signal and control cables. The shield ground bus is established and installed behind all vertical and/or horizontal terminal blocks in the distribution frames. The shield ground bus system is made up of rows of strapped (No. 22 AWG) terminals terminating the nonferrous shields and an insulated conductor from strapped terminals to the insulated copper ground frame distribution cable behind the vertical and horizontal terminal blocks. The insulated conductor should be brazed to the plane near the distribution frames served. If a jumper is used from the distribution cable to the signal reference plane, a minimum of No. 10 AWG stranded conductor will work. See the figures below.



FACILITY POWER AND A.C. GROUND DISTRIBUTION. (15b) 1-149

guidance GROUNDING/4 Signal Reference System



TYPICAL SIGNAL, SHIELD GROUND, BUS DISTRIBUTION SYSTEM. (15b) 1-151

guidance BONDING/1 Low-Impedance Connections

1. The purpose of material bonding at DCS facilities is to insure life-cycle, low-impedance electrical connections throughout the grounding subsystems. Creating and maintaining low-impedance electrical connections involves (1) appropriate material selection, (2) adequate surface preparation, and (3) reliable bonding procedures.

a. Appropriate material selection

1. Select the appropriate bonding connection for permanently joined bonds. Utilize exothermic welding whenever possible for permanently joined bonds. The welds must be able to support the mechanical load demands on the bonded members. Use brazing (or silver soldering) for permanently bonding copper and brass. Do not use soldered connections in either safety grounding networks or for any connection in the lightning protection subsystem. (15b) 1-154
2. Avoid pairing dissimilar metals. Metals that will be in direct contact should be as close together in the galvanic series as possible.
3. All bonds in concealed locations must be brazed or welded. Any bonds between dissimilar metals, such as between a copper wire and cast iron or steel pipe, must be sealed thoroughly against moisture to minimize corrosion. Bolted clamp connections should be made only in manholes or in grounding wells. These connections must be readily accessible for verification of integrity.
4. Select appropriate bonding connections for temporarily joined bonds. Employ alligator clips and other spring-loaded clamps only as temporary bonds. (15b) 1-155
5. Utilize cable trays as the overall bonding scheme. Bond each section of each tray to provide a continuous electrical path. (15b) 1-162
6. Ordinary clamps cannot be used on flexible conduit. Use a flared split sleeve fitted around the flexible conduit. (15b) 1-163

guidance BONDING/1 Low-Impedance Connections**b. Adequate surface preparation**

1. Join bond members together quickly after cleaning the mating surfaces. Once cleaned of all nonconductive material, a delay occurring within a corrosive environment means that the surfaces must be protected with an appropriate coating. Of course, this coating must be removed before the bond is completed. (15b) 1-155
2. Before covering the earth electrode subsystem with backfill dirt or otherwise rendering it inaccessible, visually check all joints and connections for mechanical integrity, for the absence of voids or other indications of poor bonding, and for seeing that all required interconnections are made.

c. Reliable bonding procedures

1. Utilize exothermic welding whenever possible for permanently joined bonds. The welds must be able to support the mechanical load demands on the bonded members. The following minimum requirements must also be met.
 - On members whose maximum dimension is 5 centimeters (2 inches) or less, the weld must extend completely across the side or surface of the largest dimensions.
 - On members whose largest dimension is greater than 5 centimeters (2 inches) but less than 30 centimeters (12 inches), one weld of at least 5 centimeters (2 inches) in length must be provided.
 - On members whose largest dimension is greater than 30 centimeters (12 inches), two or more welds, each not less than 5 centimeters (2 inches) in length, are to be provided at uniform spacings across the surface of the largest dimension. The maximum spacing between successive welds must not be more than 30 centimeters (12 inches).
 - At butt joints, use complete penetration welds on all members whose thickness is 0.63 centimeters (1/4 inch) or less. Where the thickness of the members is over 0.63 centimeters (1/4 inch), the depth of the weld must not be less than 0.63 centimeters (1/4 inch).
 - Fillet welds must have an effective size equal to the thickness of the members or as specified by Construction Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings (1-7).
 - At lap joints between members whose thickness is less than 0.63 centimeters (1/4 inch), double fillet welds must be provided.

guidance BONDING/1 Low-Impedance Connections

2. Take special care to insure that all metallic lines, such as water lines, sewer lines (if metal), and armored cable are carefully bonded to the earth electrode subsystem. Bonding jumpers of 1/0 AWG or larger bare copper wires are to be used for this purpose.
3. Bond long spans of tubing and conduit to the structure at both ends and at several intermediate points.
4. All structural bolted connections must conform to the torque requirements of the table shown on the next page. (15b) 1-23
5. Protect bonds from corrosion. Do not allow moisture or other electrolytes to enter the bond area. (15b) 1-157

MINIMUM TORQUE REQUIREMENTS FOR BOLTED BONDS (15b) 1-55

Bolt size	Threads/inch	Min. torque (inch-pounds)	Tension (pounds)	Bond area (square inches)
#8	32	18	625	0.416
	36	20	685	0.456
#10	24	23	705	0.470
	32	32	940	0.626
1/4 inch	20	80	1840	1.225
	28	100	2200	1.470
5/16 inch	18	140	2540	1.690
	20	150	2620	1.750
3/8 inch	16	250	3740	2.430
	24	275	3950	2.640
7/16 inch	14	400	5110	3.400
	20	425	5120	3.420
1/2 inch	13	550	6110	4.070
	20	575	6140	4.090
5/8 inch	11	920	7350	4.900
3/4 inch	10	1400	9300	6.200
7/8 inch	9	1950	11100	7.400
1 inch	8	2580	12900	8.600

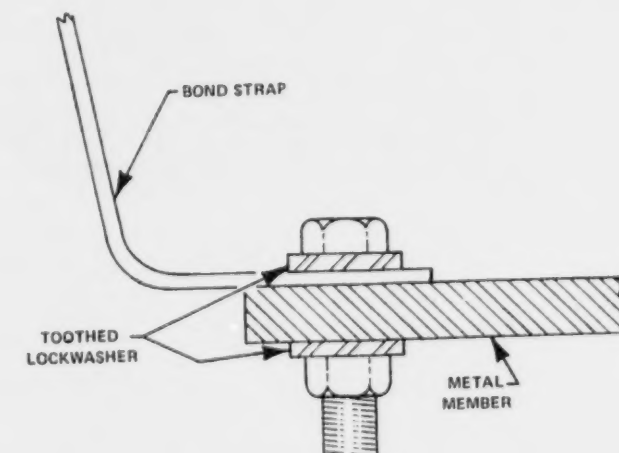
6. The mating surfaces of bolted and other compression type bonds require careful cleaning. The basic requirements are: (15b) 1-156

- All nonconductive material must be removed. These materials include paints and other organic finishes; anodized films; oxide and sulfide films; and oil, grease and other petroleum products.

guidance BONDING/1 Low-Impedance Connections

- All corrosive agents must be removed. These agents include water, acids, strong alkalis, and any other materials that provide conductive electrolytic paths.
 - All solid matter that would interfere with the establishment of a low-resistance path across the bond interface or which forms a wedge or barrier to keep the bond area open to the entrance of corrosive materials or agents must be removed. Such solid materials include dust, dirt, sand, metal filings, and corrosion by-products.
7. For bonds of high reliability, corrosion must be prevented by (1) avoiding the pairing of dissimilar metals and (2) preventing the entrance of moisture or other electrolytes into the bond area.

Metals to be in direct contact should fall together as close as possible in the galvanic series. Compatible groupings of the common metals are given in the table below. The corrosive action between metals of different groups will be greatest when the metallic union is openly exposed to salt spray, rain, or other liquids. The less exposed the bond, the less the rate of corrosion. The relative degrees of exposure may be defined as follows: (15b) 1-157



ORDER OF ASSEMBLY FOR BOLTED CONNECTION. (15b) 1-156

guidance BONDING/1 Low-Impedance Connections

COMPATIBLE GROUPS OF COMMON METALS (15b) 1-57

Group	Metals
I	Magnesium
II	Aluminum, aluminum alloys, zinc, cadmium
III	Carbon steel, iron, lead, tin, lead-tin solder
IV	Nickel, chromium, stainless steel
V	Copper, silver, gold, platinum, titanium

Exposed: Open, unprotected exposure to weather.

Sheltered: Limited protection from direct action of weather. Locations in louvered housings, sheds, and vehicles offer sheltered exposure.

Housed: Located in weatherproof buildings.

When bonds under these different exposure conditions must be made between different groups, they should be protected as indicated by the following table. Condition A means the couple must have a protective finish applied after metal-to-metal contact has been established so that no liquid film can bridge the two elements of the couple. Condition B means the two metals can be joined with bare metal exposed at junction surfaces. The remainder of the bond must be given a suitable protective finish. Condition C indicates that the combination cannot be used except under very unusual circumstances where short life expectancy can be tolerated or when the equipment is normally stored and exposed for only short intervals. Protective coatings are mandatory. (15b) 1-157

guidance BONDING/1 Low-Impedance Connections

BOND PROTECTION REQUIREMENTS (15b) 1-158

Condition of exposure	Anode				Cathode
	I	II	III	IV	
Exposed Sheltered Housed	A A A	A A A			II
Exposed Sheltered Housed	C A A	A B B	B B B		III
Exposed Sheltered Housed	C A A	A A B	B B B	B B	IV
Exposed Sheltered Housed	C A A	C A B	C A B	A B B	V

guidance BONDING/1 Low-Impedance Connections

PROTECTIVE FINISHES FOR BOND MEMBERS (15b) 1-159

Type bond	Finishing requirements
1. Between similar metals	
A. Clad and corrosion-resistant aluminum (6061)	Clean and deoxidize.
B. Noncorrosion-resistant aluminum	Chemically treat per MIL-C-5541 [1-9] using colored inspectable coating on both members of joint (Alodine 600, Iridite 14).
C. Steel (alloy and carbon)	If entire part is finished, plate with tin, MIL-T-10727, Type I or II. If only faying surface is finished, plate with tin using brush plating method.
D. Corrosion-resistant steel (18-8 stainless steel)	Clean per TT-C-490 [1-11] Method I (abrasive) or Method VI (phosphoric acid etch) for machined surfaces.
E. Copper and copper alloys	If entire part is finished, plate with tin, MIL-T-10727, Type I or II. If only faying surface is finished, plate with tin using brush plating method.
2. Dissimilar metals	
A. Corrosion-resistant aluminum mated with the following metals:	Clean and deoxidize.
(1) Noncorrosion-resistant aluminums	Chemically treat per MIL-C-5541, colored inspectable coating (Alodine 600, Iridite 14).
(2) Steel (alloy and carbon)	If entire part is finished, plate with tin, MIL-T-10727, Type I or II. If only faying surface is finished, plate with tin using brush plating method.
(3) Copper and copper alloys	If entire part is finished, plate with tin, MIL-T-10727, Type I or II. If only faying surface is finished, plate with tin using brush plating method.
(4) Corrosion-resistant	Clean per TT-C-490, Method I (abrasive) or Method VI (phosphoric acid etch).
B. Noncorrosion-resistant aluminum mated with the following metals:	Chemically treat per MIL-C-5541, colored inspectable coating (Alodine 600, Iridite 14).
(1) Steel (alloy and carbon)	If entire part is finished, plate with tin, MIL-T-10727, Type I or II. If only faying surface is finished, plate with tin using brush plating method.
(2) Copper and copper alloy	If entire part is finished, plate with tin, MIL-T-10727, Type I or II. If only faying surface is finished, plate with tin using brush plating method.
(3) Corrosion-resistant steel	Clean per TT-C-490, Method I (abrasive) or Method VI (phosphoric acid etch).

guidance BONDING/1 Low-Impedance Connections

C. Steel (alloy and carbon) mated with the following metals:	If entire part is finished, plate with tin, MIL-T-10727, Type I or II. If only faying surface is finished, plate with tin using brush plating method.
(1) Copper and copper alloys	If entire part is finished, plate with tin, MIL-T-10727, Type I or II. If only faying surface is finished, plate with tin using brush plating method.
(2) Corrosion-resistant steel	Clean per TT-C-490, Method I (abrasive) or Method VI (phosphoric acid etch).
D. Copper and copper alloys	If entire part is finished, plate with tin, MIL-T-10727, Type I or II. If only faying surface is finished, plate with tin using brush plating method.
(1) Corrosion-resistant steel	Clean per TT-C-490, Method I (abrasive) or Method VI (phosphoric acid etch).

8. Acceptable fastener materials for bonding aluminum and copper jumpers to structures are indicated in the following table. The arrangement of the metals is in order of decreasing galvanic activity. The screws, nuts, and washers to be used in making the connections as indicated are:

Type I - Cadmium- or zinc-plated steel, or aluminum

Type II - Passivated stainless steel.

When either type of securing hardware is indicated, Type II is preferred from a corrosion standpoint.

METAL CONNECTIONS FOR ALUMINUM AND COPPER JUMPERS (15b) 1-161

Metal structure (outer finish metal)	Connection for aluminum jumper	Screw type	Connection for tinned copper jumper	Screw type
Magnesium and magnesium alloys	Direct or magnesium washer	Type I	Aluminum or magnesium washer	Type I
Zinc, cadmium, aluminum and aluminum alloys	Direct	Type I	Aluminum washer	Type I
Steel (except stainless steel)	Direct	Type I	Direct	Type I
Tin, lead, and tin-lead solders	Direct	Type I	Direct	Type I or II
Copper and copper alloys	Tinned or cadmium plated washer	Type I or II	Direct	Type I or II
Nickel and nickel alloys	Tinned or cadmium plated washer	Type I or II	Direct	Type I or II
Stainless steel	Tinned or cadmium plated washer	Type I or II	Direct	Type I or II
Silver, gold and other precious metals	Tinned or cadmium plated washer	Type I or II	Direct	Type I or II

guidance SHIELDING/1 Containing Equipment RFI

A comprehensive approach to the shielding of equipment from radio frequency interference (RFI) involves (1) a building layout to optimize inherent facility shielding conditions, (2) appropriate location of all electronic equipment and signal cables, and (3) selection of effective shielding materials and construction components.

a. Building layout considerations that optimize inherent facility shielding conditions

1. Several steps can be taken during the design and construction of a facility to minimize subsequent common-mode noise problems in instrumentation, equipment, and systems. The recommended steps are appropriate for interference control in general and are not limited strictly to common-mode noise. (15b) 1-178
2. Limit openings (windows, doors, ventilation ports) and penetrations (signal lines, power lines, utilities) to the lowest possible number and restrict their dimensions to a minimum.
3. Electrical power equipment such as transformers, line voltage regulators, motors, generators, and switching devices should be separated as far as possible from data system equipment and conductors. The architectural arrangement of the facility should allow for the maximum distance between these devices and the data systems. This requirement also applies to heating, ventilating, and air-conditioning equipment, which utilize electric motors and high amperage switching devices. The maximum distance will be limited by the voltage drop which can be tolerated in feeders to the system equipment.
4. Sensitive data and instrumentation facilities should be located as far as possible from high voltage (66 kilovolts and above) transmission lines.
5. For large shielded enclosures where high traffic volume is expected, consider the use of waveguide below-cutoff hallways. (15b) 1-177

b. Appropriate location of all electronic equipment and signal cables

1. Locate sensitive and critical equipment as close to the core of the structure as operational requirements will permit. Also, identify the location of likely sources of interference such as power substations, engine-generators, and radio frequency transmitters, and maximize the separation between such sources and potentially susceptible equipment or systems. (15b) 1-173
2. The routing of data and signal lines should be perpendicular to main power lines wherever possible. Where parallel runs

guidance SHIELDING/1 Containing Equipment RFI

cannot be avoided, maximum separation must be maintained. In many instances, it may be necessary to route the data and signal in a ferrous conduit.

3. Distribution factors to the facility should be routed perpendicularly to high-voltage power lines, if possible. In any case, long parallel runs between distribution feeders and the main power line should be avoided.
4. Group power and signal lines to limit external ground loops.

c. Selection of effective shielding materials and construction components

Several steps can be taken during the design and construction stages of a facility to minimize subsequent common-mode noise problems in instrumentation, equipment, and systems. The recommended steps should be recognized as being appropriate for interference control in general and not limited strictly to common-mode noise. (15b) 1-178

1. Do not expect common building materials such as brick, concrete, wood, fiberglass, or plastic to shield significantly against electromagnetic signals. Reinforced concrete does offer a small amount of shielding, typically 10 to 20 decibels. Whenever possible, select metals with good shielding properties. (15b) 1-174
2. The selection of a shielding material can be done in two ways, either of which is acceptable. (15b) 1-174
 - Choose a metal of a given thickness and then determine that the shielding effectiveness is equal to or greater than the field attenuation desired.
 - Start with the desired attenuation and determine what thickness of metal sheet or what type of screen is required.
3. Welded seams are highly desirable in enclosures which must provide a high degree (80 decibels or more) of RF shielding or are intended for EMP protection. Where welding is impractical, solder or knitted wire gaskets should be used to supplement the mechanical fasteners. See "Bonding," above.
4. Use "honeycomb" to shield ventilation ports wherever possible.
5. Use wire screen or conductive glass to cover all openings required for visual access. Insure that the screen or glass is carefully bonded to the enclosure around the perimeter of the opening.
6. Doors should be metal, with solid uniform contact around the edges. Wire mesh gaskets or finger stock should be provided.

guidance SHIELDING/1 Containing Equipment RFI

7. Where overhead distribution lines are necessary, pre-assembled aerial cable should be used in preference to open wires. Since the conductors of pre-assembled aerial cable are twisted, the associated magnetic field is greatly reduced.
8. All internal distribution power conductors near sensitive test and measurement facilities and carrying more than 5 amperes should be twisted. A suggested rate of twist is one complete twist for each length equal to approximately 25 times the diameter of the insulated power conductor. (15b) 185
9. Metallic enclosures should be used for power conductors wherever possible to take advantage of the shielding they offer. In order of preference, the types of enclosures recommended are:
 - Conduit--From the standpoint of noise reduction, rigid steel conduit is best enclosure for power conductors and should be used wherever practical. Electrical metallic tubing (EMT) and rigid aluminum or copper conduit provide effective electrostatic shielding, but their magnetic shielding properties are poorer than rigid steel conduit by at least one order-of-magnitude.
 - Cable armor--Armored cable is sometimes used instead of conduit and individual insulated conductors. The armor provides an effective electrostatic shield but is not as effective as rigid steel conduit for magnetic shielding. Steel armor is preferable to aluminum or bronze.
 - Flexible conduit--Because of its construction, standard construction-grade flexible conduit is a poorer electrostatic shield than either of the above and provides considerably less magnetic shielding than does rigid steel conduit. The use of flexible conduit should be restricted to short lengths and only where required to absorb vibration or to permit position adjustment of the equipment or device served.
 - Wireway or cable tray--Wireways, which are rectangular sheet metal duct-like enclosures, and cable trays are not nearly as effective for electrostatic or magnetic shields as rigid steel conduit. Unless the wireway or cable tray is made of ferrous metal and all discontinuities are bonded carefully, its use for the shielding of power conductors should be limited.
10. Equip all power lines supplying shielded areas with power line filters. Power line filters are often specified to meet attenuation requirements according to MIL-STD-220 tests.
11. Use steel conduit. Steel is a very effective shield and is relatively economical.

guidance SHIELDING/2 Containing Radio Signals

12. Use enclosed metal wiring ducts or raceways. Enclosed metallic systems reduce electromagnetic coupling to electrical power and signal conditions.
13. Use squirrel cage induction motors, which do not utilize slip rings or commutators, wherever possible.
14. Where necessary to specify motors with commutators, specify those properly designed to minimize arcing. Arcing at the commutator or slip rings can be decreased by careful mechanical design, such as requiring adequately sized shafts and bearings which maintain concentricity to minimize brush bounce and vibration.
15. Securely bond all seams and joints and securely ground all shields.
16. When transducers and associated processing devices are to be installed as an integral part of facility, the instrumentation system must be designed and installed such that it does not compromise the single-point signal-ground networks used by other lower frequency systems. In particular, when the systems interface, care must be taken to ensure that the grounding integrity of each is maintained.

Derive the a.c. power for the test equipment from the same branch circuit supplying the equipment or system being measured. If this practice raises system reliability problems, low amperage breakers or fuses should be provided for the test equipment outlets. If the outlets for test equipment cannot be connected to the branch circuits feeding the primary equipment, then the test equipment branch circuit should be restricted to test equipment use. In particular, rotating machinery, industrial machines, appliances, vending and office machines, and any other non-EMI protected equipment should not be connected to that branch circuit. (15b) 1-186

2. Guidance for TEMPEST shielding and grounding procedures is available in two National Security Agency (NSA) documents. Guidelines for Facility Design and RED/BLACK Installations, reference 133, and Shielded Enclosures, reference 132.

The national policy objective is to assure that national security information is not lost through unintentional emanations. To achieve this, equipment should be designed to meet TEMPEST requirements and should be tested to verify compliance with TEMPEST specifications. However, poor installation practices can create system or facility problems even though all system components are TEMPEST acceptable. In addition, many installations may be using non-TEMPEST approved equipment; in these instances, proper facility design is imperative.

guidance SHIELDING/2 Containing Radio Signals

The red/black concept is the basis for the facility criteria presented here. The red/black concept dictates that electrical and electronic circuits, components, equipment, systems, and so forth which handle national security plain-language information in electrical signal form (red) be separated from those which handle encrypted or unclassified information (black). Under this concept, red and black terminology is used to clarify specific criteria relating to the difference between such circuits, components, equipment, and systems, and the areas in which they are contained.

Red/black guidelines have been developed which detail the procedures required to provide proper equipment and shielding, separation, grounding and filtering so that TEMPEST signals are contained in the current edition of reference 133.

Creating and maintaining a shielding system to contain all telecommunication emanations involves (1) selecting effective enclosure materials, (2) reliable construction details to maintain shielded integrity, and (3) appropriate filters and isolators.

a. Selection of effective enclosure materials

The use and selection of shielded enclosures is based on information, classification, user requirement, and geographical location of facility (CONUS and overseas), ability to control the area immediately around the facility, and TEMPEST characteristics of equipment to be used. Since the purpose of the enclosure is to attenuate all forms of conducted as well as radiated emanations, the actual equipment installation requirements within the enclosure are the responsibility of the engineering-installation agency. The three preferred types of enclosures are solid steel, armored plywood, and aluminum foil.

1. Attenuation trade-offs--Magnetic (H) fields and electric (E) fields are attenuated through absorption and reflection losses. H-field losses occur mainly because of the absorption of energy in magnetic materials such as steel. The loss in steel largely depends on the thickness of the material; consequently, solid steel enclosures provide the most H-field shielding of the three enclosure types. Similarly, armored plywood enclosures provide increasing H-field shielding effectiveness by increasing the thickness of the armor. Understandably, aluminum foil enclosures exhibit poor H-field attenuation characteristics, due to the extremely thin foil of nonferrous material. In contrast to H-field losses, E-field losses are largely due to reflection of energy off the enclosure surfaces. Both solid steel and armored plywood enclosures provide similar reflecting surfaces and, consequently, similar E-field attenuation values. Aluminum foil also has a good reflecting surface which results in moderate E-field attenuation values. The maximum obtainable attenuation values for any enclosure will depend greatly on the quality of construction. (133) 0-1

guidance SHIELDING/2 Containing Radio Signals

2. Fundamentals--The shielding effectiveness of any enclosure depends on the electrical continuity between the various parts of the room. Ideally, the enclosure should be a continuous, six-sided sheet of metal. However, some openings, such as doors, air vents, and penetrations for pipes and electrical lines, are essential. The door is potentially the weakest point of any enclosure. Although a closed door should provide as much attenuation as the rest of the structure, to be effective it must form an electrical continuity between itself and the rest of the enclosure. Consequently, enclosure doors must be constructed sturdily to prevent sagging and warping, which leads to leakage. Air vents for enclosures are made from waveguide sections bonded together to form a grill which is electrically bonded to the enclosure. Each waveguide, acting as a high-pass filter, provides at least as much attenuation as the enclosure for the same frequencies. However, when a conductive line or duct must be used, 6-inch nonconductive coupling should be used outside the enclosure as close to the wall as possible, preferably less than 2 inches away. (132) 3-1

It is relatively easy to achieve the required shielding effectiveness in a welded box without openings and penetrations. However, to preserve this performance in a real facility with numerous penetrations requires careful attention to each of these potential leakage points. The table below is a typical example of penetration details that must be written into contract documents for a communication facility.

guidance

SHIELDING/2 Containing Radio Signals

SHIELD PENETRATION SCHEDULE.

Room No.	Penetration		Type of Penetration	Location		Det./Shp.	Remarks
	No.	Size		Room	Area		
100	1	2" Ø	DRINKING FOUNTAIN WASTE PIPE	•		P/M-6	WELD PIPE TO LINER
101	2	4" Ø	WASTE LINE CLEANOUT	•		J/M-6	WELD PIPE TO LINER
101	2	3" Ø	FLOOR DRAIN	•		J/M-6	WELD PIPE TO LINER
101	1	2" Ø	PLUMBING VENT	•		Q/M-6	WELD PIPE TO LINER
101	1	1-1/2" Ø	FIRE SPRINKLER TEST CONNECTION	•		A/M-6	WELD PIPE TO LINER
102	1	4" Ø	PLUMBING VENT	•		Q/M-6	WELD PIPE TO LINER
102	4	1" Ø	HEAT EXCHANGER COOLANT LINES	•		A/M-1	WELD PIPE TO LINER
102	2	3" Ø	FLOOR DRAIN	•		J/M-6	WELD PIPE TO LINER
103	3	3" Ø	FLOOR DRAIN	•		J/M-6	WELD PIPE TO LINER
103	1	24" x 24"	EXHAUST FAN WAVE GUIDE	•		S/M-7	4" x 4" HONEYCOMB MATRIX
103	1	40" x 40"	AIR INTAKE WAVE GUIDE	•		E.F. G/A-10	4" x 4" HONEYCOMB MATRIX
103	1	16" Ø	BOILER FLUE	•		V/M-7	PIPE SLEEVE WELD TO LINER
104/106	1	4" Ø	SOIL PIPE	•		P/M-6	WELD PIPE TO LINER
104/106	1	4" Ø	PLUMBING VENT	•		Q/M-6	WELD PIPE TO LINER
104	1	2" Ø	FLOOR DRAIN	•		J/M-6	WELD PIPE TO LINER
106	1	2" Ø	FLOOR DRAIN	•		J/M-6	WELD PIPE TO LINER
106	1	8" x 10"	EXHAUST FAN WAVE GUIDE	•		S/M-7	4" x 4" HONEYCOMB MATRIX
107	1	24" x 24"	REFRIGERANT LINES/PLATE	•		D.E/M-2	26" x 26" PLATE WELD TO LINER
108	2	3/4" Ø	DIESEL OIL GAGE	•		P/M-6	WELD PIPE TO LINER
108	4	3/4" Ø	DIESEL OIL LINES	•		P/M-6	WELD PIPE TO PLATE
108	3	5'-4" w x 8'-8" h	GENERATOR VENT EXHAUST	•		H/M-5	4" x 4" HONEYCOMB MATRIX
108	3	6'-8" w x 8'-8" h	GENERATOR VENT AIR INTAKE	•		E.F. G/A-10	4" x 4" HONEYCOMB MATRIX
108	1	32" x 32"	SSUP'S EQUIPMENT EXHAUST	•		S/M-7	4" x 4" HONEYCOMB MATRIX
108	1			•			26" x 26" PLATE WELD TO LINER
108	1	3" Ø	FLOOR DRAIN	•		J/M-6	WELD PIPE TO LINER
109	1	3" Ø	FLOOR DRAIN	•		J/M-6	WELD PIPE TO LINER
109	1	2" Ø	DOMESTIC WATER	•		K/M-6	WELD PIPE TO LINER
109	1	2" Ø	SPRINKLER MAIN	•		K/M-6	WELD PIPE TO LINER
109	1	2" Ø	GAS PIPE	•		K/M-6	WELD PIPE TO LINER
109	1	12" x 16"	EXHAUST FAN WAVE GUIDE	•		W/M-7	4" x 4" HONEYCOMB MATRIX
109	2	1" Ø	HEATING WATER	•		K/M-6	WELD PIPE TO LINER
110	1	2" Ø	FLOOR DRAIN	•		J/M-6	WELD PIPE TO LINER
121	1	3' x 7'	DOOR 101B	•		A-13	
108	1	6' x 7'	DOOR 108B	•		A-13	
110	1	1/2" Ø	ELECTRICAL POWER CONDUIT	•		C/E-8	POWER FILTER SHALL BE 1-2W, 120V, FILTRON FSR-X-15B2 OR APPROVED EQUAL
101	4	4" Ø	CONDUITS FOR FUTURE COMM. CABLES	•		DETAIL 1/C-5	CAP ALL ENDS
102	2	10" Ø	ANTENNA CABLE CONDUITS	•		A/C-5	
102	1	3/8" Ø	3/8" STEEL STUD	•		B/E-6	FOR ATTACHMENT OF 410 CABLE
103	2	1" Ø	CONDENSING UNITS POWER CONDUIT	•		B/E-8	POWER FILTERS SHALL BE SUITABLE FOR UNITS PROVIDED. SEE SPEC. SECT. 13C
103	1	1-1/4" Ø	CONDENSING UNITS CONTROL CONDUIT	•		B/E-8	CONTROL FILTERS SHALL BE SUITABLE FOR CONDENSING UNITS PROVIDED. SEE SPEC. SECT. 13C
111/109	4	4" Ø	ELECTRICAL POWER CONDUITS	•		B/E-8	
111	1	1/2" Ø	FIRE ALARM	•		B/E-8	
112	1	1/2" Ø	FIRE ALARM	•		B/E-8	
112	1	6" Ø	300 PAIR TELEPHONE FILTER	•		B/E-8	

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3. Construction trade-offs--A shielded enclosure of any type must be constructed properly to provide optimum shielding effectiveness. Construction of solid steel enclosures is most elaborate since specialized tools and labor are necessary. However, both armored plywood and aluminum foil enclosures can be assembled with only common tools and labor. Aluminum foil enclosures have an additional advantage--they use commonly available materials. On the other hand, the panels and hardware for both solid steel and armored plywood enclosures must be supplied through an enclosure manufacturer. However, foil enclosures take more time to construct than other types of rooms, especially when inexperienced help is employed. This fact should be considered when time is important. (132) 3-1

4. Installation characteristics--Some installation characteristics will influence the choice of an enclosure. Location, floor loading, and portability are three considerations. (132) 3-2

Location--The location of an enclosure in a parent room can minimize potential weak points. Since access doors are potentially the weak area of an enclosure, locate the doors in an area closest to the center of the control zone where leakage will be least detectable. Furthermore, locate the enclosure where the fewest penetrations will be necessary. Find an area with the fewest pipes, ducts, and so forth to interfere with construction. Each penetration is a possible leakage point. Also, the enclosure walls should be at least 18 inches from the parent room's walls to facilitate construction, testing, inspection and maintenance. If an 18-inch separation is impractical, take precautions to prevent clandestine probing or penetration possibilities. Attempt to locate the enclosure close to a grounding point to avoid long ground wire runs. Ground the enclosure to an earth ground at the main power entrance panel. When an earth ground is not feasible, use a connection to a.c. ground external to the enclosure.

Floor loading--The weight of some enclosures, especially solid steel enclosures, will limit the placement to ground-level floors or will require additional floor supports. Determine the floor loading limits of the enclosure site to insure that the floor can support the enclosure.

Portability--A constantly expanding and/or relocating system may require a constantly expanding and/or relocating enclosure. For such systems, choose an enclosure which can be enlarged or moved as easily as possible.

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5. Cost trade-offs--Construction costs for any enclosure are divided between material cost and labor cost; the latter is the major part. In most instances, armored plywood enclosures will cost less than solid steel for smaller rooms (up to 16-foot widths). Beyond 16-foot widths, steel and armored plywood enclosures are competitive because additional ceiling supports for armored plywood rooms may be necessary. For larger rooms (greater than a 16-foot width) where extra structural supports for armored plywood are necessary, steel rooms can be more cost effective. Although foil enclosure materials are cheaper than other enclosure materials, the labor cost to construct a foil enclosure can offset savings in material costs. If in-house labor is available, a relatively inexpensive foil enclosure can be constructed. Another option would be to use in-house labor to build an armored plywood enclosure which can be shipped from the manufacturer to the installation site as a complete package.

Installation--Installation costs will be greater for solid steel and armored plywood rooms if additional components such as floor supports are necessary to bear the weight. Also, a minimum distance of 2 feet between enclosure and parent room wall is suggested for work spaces and inspections. The enclosure can be moved after it is installed, but at a high labor cost. An armored plywood enclosure is the most portable kind. It can be assembled and then disassembled and moved. Also, those enclosures bolted from the inside eliminate the need for work space between the enclosure and parent room walls. Aluminum foil enclosures require no work space between their own walls and parent room walls. Furthermore, such enclosures are not portable. Installation costs must also include some protective covering for the foil surfaces.

Maintenance--Maintenance costs for solid steel and aluminum foil enclosures will be low if they are properly constructed. Armored plywood enclosures will require frequent inspection and repair of damaged or corroded door surfaces and loosened seam bolts. (132) 3-6

6. Alternative countermeasures

Equipment modifications--An enclosure may not be the most cost-effective way to eliminate a C-E hazard. In many cases, equipment or system modifications may be possible to reduce the C-E to a level that can be adequately contained within available control zone boundaries. Also, a change in system components or modifications in equipment may eliminate completely or reduce C-E sufficiently to allow an aluminum foil enclosure over a solid steel enclosure. This will afford adequate protection. The choice of system or equipment modifications will depend on the availability, price, and quantity of modifications needed.

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Control zone modifications--To provide TEMPEST security, a change in control zone may be more cost effective than building an enclosure or modifying equipment/systems. A trade-off would be to expand the control zone enough to permit the use of an aluminum foil enclosure over an armored or solid steel enclosure.

Trade-off consideration--Knowing what control zone perimeter is necessary for TEMPEST security, consider the trade-offs available. Either expand the control zone perimeter to the distance needed to minimize the hazard, modify or replace the hazardous equipment/system, shield the equipment/system, or combine these choices in the most cost-effective manner. (132) 3-7

7. Solid steel enclosures

The solid steel enclosure is constructed from steel panels of 16-gage to 3/8-inch thickness welded at the seams to a steel beam superstructure. The building materials and construction procedures require special heavy equipment and skilled labor to assemble the room properly and quickly. The enclosure doors can be and often are massive. Often hydraulic assistance is needed not only to operate but also to maintain even metal contact pressure around the frame. (132) 3-1

Solid steel enclosure attenuation--The solid steel enclosure consists of solid steel plates, up to 9.5 millimeters (3/8 inch) thick, and welded together to provide the following typical attenuation characteristics:

- Magnetic field (H-field) attenuation: 30 decibels at 30 hertz up to 100 decibels at 1 kilohertz. Continue 100 decibels to 1 megahertz.
- Electric field (E-field) attenuation: 100 decibels from 30 hertz to 100 megahertz.
- Plane waves attenuation: 100 decibels from 100 megahertz to 10 gigahertz.
- Acoustic waves attenuation: 12 decibels at 4 hertz to 59 decibels at 7 kilohertz.

It should be noted that acoustic wave attenuation characteristics apply only to RF enclosures treated with acoustic absorbing material, not to standard RF enclosures. H-field attenuation values will decrease with decreasing steel thickness.

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Location--When placing a solid steel enclosure, the external walls should be accessible for welding the panels to the frame. There should be at least 2 or 3 feet between the enclosure and parent room walls for work space and inspections. (132) 3-2

Floor loading--Floor loading is a major consideration for steel enclosures. The weight of a solid steel enclosure demands a sturdy foundation and careful measurement of loading limits of the parent room floor. (132) 3-2

Portability--Consider the solid steel enclosure as a permanent installation. Although the enclosure could be moved, the effort and cost may be prohibitive. (132) 3-2

Construction--Construction, material, and labor costs for a moderate-size enclosure (under a 10-foot-high ceiling) will be more than for other types of enclosures. If an enclosure has a width over 24 feet, steel rooms may be more cost effective than armored plywood. The special equipment and labor needed for construction increases the overall price. (132) 3-2

Installation--Installation costs can be higher for steel enclosures because additional floor supports may be necessary to strengthen the floor area which will bear the weight of the enclosure. (132) 3-2

Maintenance--Maintenance costs for solid steel enclosures should be minimal. The welded seams will maintain electrical continuity indefinitely under all types of environmental stresses. Massive doors, however, may produce leakage from sagging or surface corrosion that prevents proper sealing with the frame. (132) 3-4

Testing--Testing costs will be approximately the same for any of the enclosures. (132) 3-2

Initial inspection:

- Look for complete welded joints, with no gaps or cracks along the seam.
- Examine the door for complete sealing around the frame. Solid steel rooms usually do not use finger stock. See that the surfaces are clean and free of marks or grooves.
- Check filters.
- Examine enclosure penetration.

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Periodic inspection--Solid steel enclosures should not be greatly affected by settling and environmental changes. Major repairs involve the access door closing and sealing operation. In addition:

- The roof should be inspected to detect any sagging, broken welds, and so forth, that may produce leakage.
- Door frames containing finger stock should be inspected. For other types of door frames, inspect for clean, smooth surfaces free of such problems as nicks and dirt, which may cause a poor seal.
- Doors using finger stock should be inspected. Doors using RF gasketing or some other sealing method should be inspected for problems that may cause a poor seal, such as wear, pitting, tears, and gaps.
- Filters should be inspected.
- Air filters should be inspected. (132) 3-5

8. Armored plywood enclosures

Armored plywood--Armored plywood enclosure panels consist of 24-gage or thicker steel sheets bonded to both sides of a 3/4-inch plywood panel. The 4- by 8-foot or 4- by 10-foot panels are bolted together using steel channel pressure plates and large diameter bolts torqued down to provide even metal contact for electrical continuity. Room construction does not require the specialized equipment or labor necessary for steel rooms. Doors for the enclosure can be operated manually or automatically. Electrical contact between the door and the frame is accomplished by placing bronze or copper contact strips (finger stock) around the door jamb. Upon closing, the strips uniformly contact a copper or brass door buck to form a seal. (132) 3-1

Armored plywood enclosure attenuation--The enclosure is composed of 19-millimeter (3/4-inch) plywood with steel panels (24 gage or thicker) bonded to both sides and assembled with bolts. The typical attenuation profile for 24-gage steel armor follows:

- Magnetic field (H-field) attenuation: 20 decibels at 1 kilohertz rising to 100 decibels at 1 megahertz.
- Electric field (E-field) attenuation: 70 decibels at 1 kilohertz to 100 decibels from 10 kilohertz to 100 megahertz.
- Plane waves attenuation: 100 decibels from 100 megahertz to 10 gigahertz.

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- Acoustic waves attenuation: 12 decibels at 4 hertz to 59 decibels at 7 kilohertz. (133) 0-1

It should be noted that acoustic wave attenuation characteristics apply only to RF enclosures treated with acoustic absorbing material, not to standard RF enclosures.

Location--There should be at least 18 inches between the walls of armored plywood enclosures bolted from the outside and the parent room walls. This facilitates installation and inspection. Some enclosures are bolted from the inside and circumvent this space requirement, but this arrangement also prevents the periodic inspection of the external walls. (132) 3-2

Floor loading--Floor loading can also be a problem with armored plywood enclosures. Compare the extra weight of the enclosure to the floor loading limits as a safety precaution. (132) 3-2

Portability--Armored plywood enclosures can be adapted to changing space requirements. Additional panels may be added for expansion, or the entire room disassembled, moved, and re-assembled. (132) 3-3

Construction--Construction materials and labor costs for armored plywood enclosures will be cheaper than solid steel enclosures for standard room sizes (floor length dimensions in multiples of a 4-foot width less than 24 feet, with 8- or 10-foot ceilings). Also, armored plywood enclosures come in kit packages which can be assembled by local unskilled labor, potentially reducing construction costs. However, inexperienced laborers may degrade attenuation levels if they assemble the enclosure improperly. (132) 3-3

Installation--Installation costs will be moderate since extreme floor loading precautions will usually not be necessary. Armored plywood enclosures also are more cost effective when an enclosure will be moved or expanded frequently. (132) 3-3

Maintenance--Maintenance costs will be greater than for other types of enclosures since broken finger stock and loosened bolted seams will need periodic inspection, adjusting, and retesting to continue the level of shielding effectiveness. (132) 3-3 Armored plywood enclosures are susceptible to loosened seams and sagging roof panels. Frequent inspection of the enclosure, especially just after installation, is necessary to detect loose bolts. Any loose bolts should immediately be retightened to uniform specified torque; the bolts should be tested for leakage. Doors will require continuing maintenance for damaged or missed finger stock, sagging doors, and corroded door and seam surfaces. (132) 3-4

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Testing--Testing costs will be about the same as for any other type of enclosure. (132) 3-3

Initial inspection:

- Look for crooked joints in the framing and for missing bolts. Check the roof for sag.
- Examine the door for bent, missing, or dirty contact fingers. Check the frame for dents, deep scratches, or corrosion.
- After external power lines are connected to filters, check all filters for damaged seals and for missing or loose lids. Insure that filter cases are mounted with a good electrical bond to the enclosure wall.
- Examine penetrating pipes and ducts and their bond to the enclosure. Insure that a nonconducting section is placed outside the enclosure along the penetrating item to isolate it from the enclosure.

Periodic inspections--After an enclosure has been used for a few months, settling of the enclosure or the parent room may loosen the joints. In addition, repeated expansion and contraction from changing atmospheric conditions may cause the wood in armored plywood panels to lose its elasticity. Usually loose joints cannot be detected by visual inspection, but the exterior surfaces of the enclosure should be examined for bulges, distorted framing, or signs of corrosion.

- The roof should be inspected to determine the amount of sagging, if any.
- The door frame "contact pattern" is a good indicator of potential RF leakage. This pattern consists of marks or scratches made by the metal door fingers. If the scratches are evenly spaced and of approximately equal depth, and if the fingers and the door frame are clean and shiny, RF leakage is unlikely. If the contact pattern is deep at one corner and gradually fainter toward the opposite corner, the door is probably sagging at the hinges; RF leakage is likely to occur where the pattern is faint. If irregular light spots appear, the fingers at corresponding points on the door are probably flattened or missing. Leaking is almost certainly occurring at these points. Deep gouges in the door frame may occur where the frame touches the latching mechanism, possibly causing leakage paths for high-frequency signals. Dents or severe wear near the handle usually indicate a misaligned latch. Since dust and corrosion are poor conductors, they are also sources of RF leakage.

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- The door finger stock should be examined for damage and corrosion, especially at points corresponding to light contact patterns on the door frame. Broken or bent fingers are most likely to be found at the corners of the door and in the latch area. Accessible portions of the latching mechanism should be examined for wear and operated to detect binding or scraping. If there is an emergency escape hatch which can be opened easily, without major repairs necessary to close it, the hatch should be inspected and operated every 6 months. Each hinge should be inspected for sag by measuring the spacing between the hinge pin and the frame. The spacing should be uniform along the pin.
- Filters should be inspected for leakage of potting compound. RF leakage may occur if the hardware between the shield and the filter has worked loose, or if there is a poor electrical bond between the filter case and its lid. If the lid is dented or loose, it should be replaced. If the filter is leaking potting compound, an oily or viscous material oozes from the seams in the filter case. The physical properties of this material vary with the manufacturer, but any visible exudation indicates a potentially defective filter. Causes may be overheating from current overload, internal defects, or poor air circulation.
- Air filters covering the ducts should be inspected and cleaned, especially if the opening of the duct is near the floor. (132) 3-4

9. Aluminum foil enclosures

Aluminum foil enclosures are made of wooden frame walls of 2- by 4-foot studs, 1- by 4-inch furring strips or 1/2-inch plywood, a 1/2-inch plywood ceiling, and an 18-gage steel sheet floor. Four-foot wide, 2.5-m² thick embossed aluminum foil sheets cover the wall and ceiling framework in two overlapping layers. Each foil layer is stapled to the framework, and the bottom edge is pressed to the sheet steel floor by a steel bar to form a complete metal shell. Construction requires no specialized tools or labor but takes more time than do prefabricated enclosures. Extra care is necessary to avoid rips and sloppy construction. The enclosure doors are made from common steel panels with steel frames and are sealed with standard closer mechanisms. A vestibule entrance arrangement with two sets of doors is used instead of costlier custom-made enclosure doors to reduce door leakage. (132) 3-1

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Aluminum foil enclosure attenuation--The enclosure is structured from a wooden frame with thin (2.5 mil) aluminum foil sheets stapled at the joists. The attenuation profile for foil enclosures follows:

- Magnetic field (H-field) attenuation: 10 decibels at 1 kilohertz to 50 decibels at 1 megahertz.
- Electric field (E-field) attenuation: 50 decibels at 10 kilohertz to 100 megahertz.
- Plane waves attenuation: 50 decibels at 100 megahertz to 40 decibels at 1 gigahertz.
- Acoustic waves attenuation: Depends on the acoustic treatment used within the enclosure. (133) 0-1

Acoustic wave attenuation characteristics apply only to RF enclosures treated with acoustic absorbing material, not to standard RF enclosures.

Location--Except for the free-standing wooden framework, an aluminum foil enclosure is attached directly to existing parent room walls. No space is required between enclosure walls and parent room walls. The door location for aluminum foil enclosures is especially critical since special radiation-tight doors are not used and leakage is probable at high frequencies. Consequently, locate doors toward the most secure area of parent room--toward the center of the secure perimeter. If there is no space for vestibule entranceways, either seal the door with finger stock or ask the enclosure manufacturer whether an enclosure door can be purchased. (132) 3-3

Floor loading--Floor loading is not a critical consideration for aluminum foil enclosures since all materials are lightweight. (132) 3-3

Portability--Consider an aluminum foil enclosure to be a permanent installation. The building materials, although easily razed, cannot be reused. The structure can be expanded by adding additional framework and foil to the existing enclosure. (132) 3-3

Construction--Construction material for an aluminum foil enclosure will be the cheapest of any enclosure. The costliest item will be labor, and labor costs may offset savings in materials over other types of enclosures unless readily available in-house labor does the construction. The foil sheets are cheap, as are the staples, wooden framework, and so on. (132) 3-3

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Installation--Installation costs will include some protective covering installed over the foil. This covering is essential to prevent tears in the foil. Inexpensive drywall may be used as a covering. (132) 3-3

Maintenance--Maintenance costs for a well-constructed aluminum foil enclosure should be low. The primary maintenance will be the repair of tears in the shield. Some protective covers for the walls and ceiling are essential to minimize maintenance. The ceiling should be inspected periodically for sagging foil panels and tears around the metal staples. (132) 3-4

Testing--Testing costs will be about the same as for any other enclosure. (132) 3-3

Initial inspection--Before installing a protective wall, ceiling, or floor surface, an inspection will be necessary.

- Check the roof, foil panels, sagging panels, foil wall to steel floor connection, overlapping seams, and continuous bend of foil at corners. Check spot welds on steel floor seams and continuous welds at all vertical seams in the steel floor.
- Inspect doors for proper closing operation; clean contact points between frame and door. Double doors should have a metal strip covering the space between doors.
- Filters should be inspected as described in 3-9a(3).
- Penetration should be examined as described in 3-9a(4).

Periodic inspection--The main problem with foil enclosures is tears in the foil panels. Once a protective wall surface is installed, inspections are easy to make. If suspended ceilings and raised floors are used, periodic inspection of foil panels and steel floors is advisable.

- Inspect the ceiling for sagging or torn foil panels or loosening seams. The steel floor should be free of rust and corrosion.
- If a special-order enclosure door with finger stock is used, inspect the door frame and doors as described in reference 132, 5-7. Normal foil enclosure doors consist of steel panel doors and steel frames. The contact points between frame and doors should be as clean as possible. Inspect the door closely to determine that proper operation applies some contact pressure from door to frame.

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- Filters should be examined.
- Air filters should be inspected. (132) 3-5

b. Documents--Three enclosure specifications define construction, testing, and attenuation requirements for shielded enclosures. An enclosure installed to prevent the possible exploitation of classified information through analysis of C-E from communications or information-processing equipment should conform to the appropriate specification. The three NSA specifications are:

- Number 65-5, National Security Agency Specification for RF Shielded Acoustical Enclosures for Communications Equipment General Specification (30 October 1964).
- Number 65-6, National Security Agency Specification for RF Shielded Enclosures for Communications Equipment General Specification (30 October 1964).
- Number 73-2A, National Security Agency Specification for Foil RF Shielded Enclosure (15 November 1972).

Solid steel and armored plywood enclosures from most manufacturers will comply with NSA Specification 65-6. A few manufacturers sell special acoustic enclosures complying with NSA Specification 65-5. No company currently makes a foil enclosure room constructed to NSA Specification 73-2A. The foil enclosure specification is a general document which may be adapted or tailored to site-specific needs. For example, if a location does not have enough space for a vestibule entrance, the vestibule entrance may be deleted from the contractual requirement for the enclosure. Instead of a vestibule, the contract may specify special precautions to seal the seams around a standard door using RF gasketing or a standard RF enclosure door and frame. (132) 5-1

1. Construction details for solid steel and armored plywood enclosures

Design objective--Reliability to maintain continuous high attenuation characteristics shall be stressed throughout design and construction. Unless the contract excludes demountable construction, the structure shall be so constructed and assembled as to make disassembly and reassembly possible with a minimum of effort and minimum distortion to the room structure. Particular attention shall be paid to the way electrical services and other internal accessories are attached to the walls, floor, and ceiling of the enclosure, so as to provide for easy removal before the enclosure is dismantled. This shall be interpreted to include design methods that provide not only the minimum of physical effort required for installation or removal, but also that

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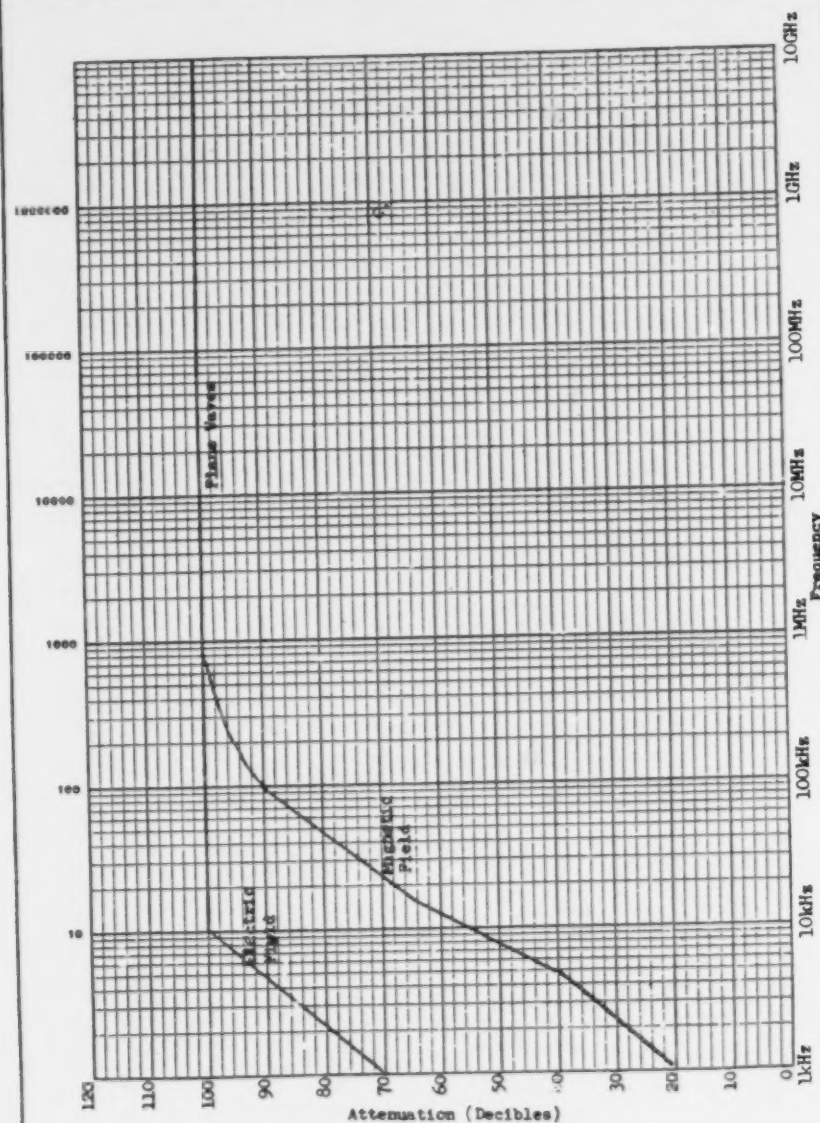
will result in no damage to devices or materials; upon any reassembly of the enclosure as a whole, the devices or materials should not lose their effectiveness. (132) B-1

Reliability--The enclosure will be subject to varying movable floor loads, frequent use of access doors, possible disassembly and reassembly, and, in most cases, continuous use of air-conditioners and filters. Withstanding such usage requires that adequate safety factors must be incorporated in the design of all components of the enclosure, and accessories and ancillary equipment. The enclosure must retain the specified attenuation at least 3 years without the need to retighten bolts or do other major maintenance. (132) B-2

Material--All materials, parts, and mechanical and electrical assemblies used in the construction and installation of the enclosure shall be new, unused, undamaged, not so old or so deteriorated as to impair their usefulness or safety, of a quality consistent with the proposed use and performance specified, and in accordance with referenced documents. When a definite material is not specified, the material used must meet the requirements of this specification. Further, material shall be free from all defects and imperfections that might affect the serviceability and appearance of the finished product. Except as specified here, the equipment and its components may be a regular commercial product of the manufacturer and his suppliers. (132) B-2

Minimum attenuation--The enclosure shall provide electric, magnetic, and plane wave attenuation--not less than that specified in the following figure--when all line filters are installed and carrying current, internal air ducts are in place, external ducts are disconnected, and the air-conditioner is not operating. (132) B-2

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REQUIRED ELECTROMAGNETIC ATTENUATION.

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Warranty--The contractor shall stipulate in writing that the enclosure(s) furnished under the requirements of this specification will meet and maintain the attenuation requirements shown in the figure for not less than 3 years after a proper initial installation. The contractor shall be responsible for the repair or replacement of any part(s) which reduces the attenuation parameters of the enclosure(s) below the levels shown in the figure.

Enclosure structure (132) B-3

Size--The size of the enclosure shall be as specified in the contract.

Framework--The framework shall be of metal. It should be strong and rigid enough to support the walls and roof without sagging or settling that would reduce attenuation below that specified herein, or 1 inch in 3 years, whichever is less. It should be possible to assemble each demountable enclosure on site without welding or soldering; bolt construction is preferred. Disassembly and reassembly without damage should be possible. The floor must not sag.

RF attenuation panels--Panel sheets shall contain solid, galvanized, heat-treated annealed steel, treated to resist corrosion without degrading electrical continuity or RF attenuation. Sheets shall be thick enough to provide the RF attenuation shown in the figure. Contact between dissimilar metals which will cause corrosion or degrade the attenuation of the enclosure shall be avoided.

Joints between panels--Joints between panels shall be constructed to meet and maintain the attenuation requirements shown in the figure without maintenance for 3 years after installation. If a bolted type of structure is used, joints shall be bolted from the inside only, unless otherwise specified in the contract.

Roof--The roof of the enclosure shall be flat and shall not sag so as to reduce attenuation below that specified herein, or more than 1 inch in 3 years, whichever is less. Supports shall be provided for enclosures whose roofs are not self-supporting. Exterior beams at each roof panel seam, supported by the side wall panels, are preferred. Hangers from the ceiling of the parent room may be used only if special permission is obtained from the contracting officer. Beams shall be security bolted to panels and hangers. Hangers shall not transfer RF radiation to the parent room.

Access doors--Access doors shall be constructed to provide the RF seal to comply with the attenuation requirements of the

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figure. At least two rows of beryllium copper finger stock shall be used to provide an RF seal all around the doors. A piano-type hinge, or ball bearing hinges of equivalent load capacity, shall be used to hang the doors.

Access door closing mechanism--The access door handles shall operate closing mechanisms that provide sufficient positive closure that the entire door area, including the juncture between the door and its frame at all points, meets the attenuation requirements of the figure. The door handles shall be operable both inside and outside the enclosure. Removable plates shall be provided, if applicable, so that the door closing mechanism can be released directly from the inside or outside if the handle mechanism fails.

Combination lock--The access doors shall be fitted with an approved three-position, dial-type combination lock equipped with an internal escape mechanism, if specified in the contract.

Size and location--The size, location, direction of swing, and number of access doors shall be as specified in the contract.

Internal structure (132) B-4

Floor--The type of flooring and floor covering shall be as specified in the contract. The floor and floor covering shall be able to withstand without damage the floor loading requirements specified in the contract.

Wall covering--Wall coverings shall be as specified in the contract.

Service entrance panel--Service entrance panels, complete with connectors and filters for the filtering of lines penetrating the enclosure, shall be fabricated into panels of the enclosure as specified in the contract.

Connectors--Signal line and power line connectors shall be as specified in the contract.

Power and signal line filters--A filter shall be provided for each incoming power line penetrating the enclosure. All power line filters shall provide a minimum of 100 decibels of insertion loss from 14 kilohertz to 10,000 megahertz. Other pertinent parameters for these and signal line filters shall be as specified in the contract. Filters shall be mounted on the outside wall of the enclosure in a way which does not degrade its attenuation.

Other electrical requirements--The service entrance panel shall include a distribution box with circuit breakers for outlets and lighting fixtures inside the enclosure as specified in

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the contract. (132) B-4

Grounding--Facilities for grounding the outside wall of the enclosure to an earth ground shall be provided. These facilities shall consist of a grounding lug attached to the enclosure panel, appropriate grounding cable, and grounding stakes driven into the earth. Where an earth ground is not feasible, materials for connection to a.c. ground external to the enclosure shall be furnished. The exact characteristics of these items shall be as specified in the contract. (132) B-4

Air-conditioning facilities--Air-conditioning facilities for the enclosure shall be provided as specified in the contract. Internal ductwork and waveguides shall be supplied by the enclosure contractor in all cases, and he shall insure that the air-conditioning installation does not degrade the attenuation of the enclosure.

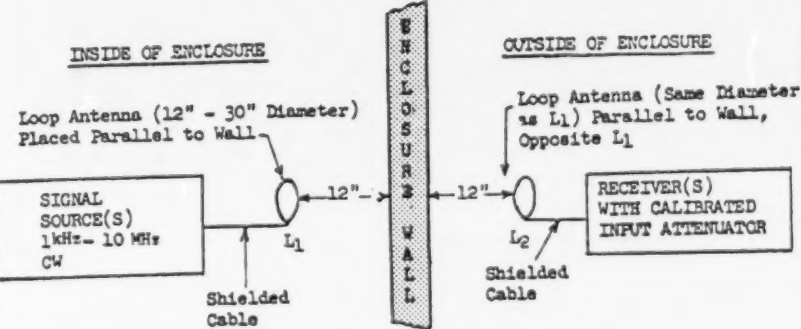
Ductwork--All ductwork shall be designed to provide the electromagnetic attenuation in compliance with the requirements of the figure.

Waveguides--All air ducts passing through the panels of the enclosure shall be attached to high-frequency electromagnetic waveguide cut-off type vents inserted in the enclosure panels to provide RF attenuation in compliance with the requirements of the figure. (132) B-4

Special tools--The contractor shall provide special and nonstandard tools required for building the enclosure which are not normally included in military tool chests. (132) B-4

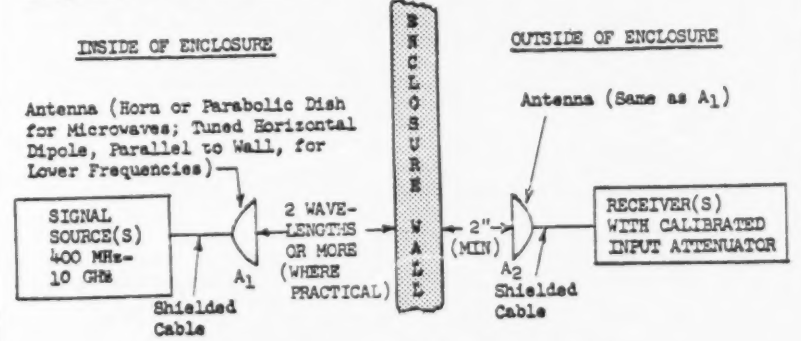
Workmanship--The enclosure and its accessories shall be constructed and finished in a thoroughly workmanlike manner, shall be free from defects which may affect appearance or serviceability, and shall conform to the requirements of this specification. (132) B-4 See "EMP/HEMP Protection" for additional construction guidance.

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TEST SET-UP FOR MAGNETIC FIELD MEASUREMENTS (1kHz-10MHz).

NOTE: Loop Antennas must be positioned for maximum pick-up. For Electric field measurements in this range, use same set-up but substitute suitable monopoles, with ground plane, for loop antennas.



TEST SET-UP FOR PLANE WAVE MEASUREMENTS (100 MHz - 10 GHz)

RF ATTENUATION MEASUREMENTS

2. Construction details for aluminum foil enclosures

Objective--The principal objective of this specification is to provide a complete operating shielded enclosure capable of meeting the performance characteristics delineated in the figure, "Required Electromagnetic Attenuation." The enclosure must also sustain the attenuation levels attained after the foil material is affixed within the enclosure. Any design work, fabrication, and construction and erection efforts shall be performed under the supervision of personnel who are aware of the consequences of substandard work. Particular care shall

guidance

be taken in coordinating the activities of the various trades utilized under the contract to insure that the shield is maintained. (132) C-2

Reliability--The entire enclosure will be subjected to continuous use with respect to variable conditions. These conditions relate to various items of equipment being moved in and out, and to the frequent use of access doors. In the functional applications of ancillary devices (such as filters and waveguides), safety factors shall be provided by suitable deratings from the applicable specification values to assure high reliability under operating conditions. The construction and installation shall include those features that will result in reliable, stable characteristics with minimum maintenance. (132) C-2

Material--All materials, parts, and mechanical and electrical assemblies used in the construction and installation of the enclosure shall be new, unused, undamaged, of a quality consistent with the proposed use and performance specified, and in accordance with referenced documents. When a definite material is not specified, the material used must meet the requirements of this specification. All nonspecified material shall be of the quality regularly used by the manufacturer in the product he sells on the commercial, as distinguished from the Governmental, supply market. Material shall be free from all defects and imperfections that might affect the serviceability and appearance of the finished product. Except where modified herein, the enclosure's component parts should be regular commercial products. The required aluminum foil and sheet metal room liner shall be provided as indicated and as specified below. Welding shall be in accordance with the code for welding in building construction of the American Welding Society. Gages of material shall be the manufacturer's standard gage. Materials and parts necessary to complete the lining, even though such work is not definitely shown or specified, shall be included. (132) C-2

Aluminum foil--Unless otherwise specified, the aluminum foil shall be equal to the Reynolds Co. .0025 inches thick, 48 inches wide, embossed finish foil.

Steel sheets--Unless otherwise specified, steel sheets shall conform to QQ-S-698, hot or cold rolled as required.

Screws--Unless otherwise specified, the screws shall conform to the following specifications: FF-S-85, FF-S-92, FF-S-111, and FF-S-325.

Doors--Solid panel metal fire doors and metal door frames shall be used.

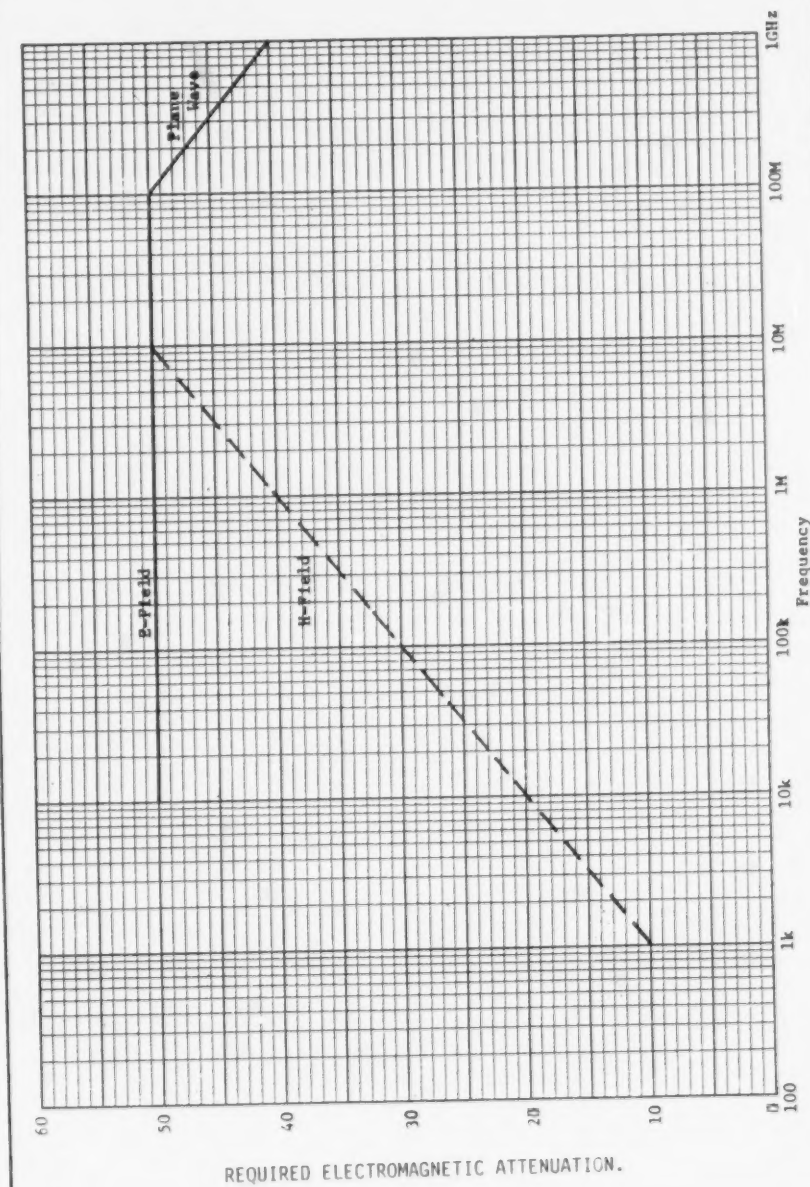
Waveguides--The waveguide for fresh air and exhaust air ducts shall be the manufacturer's standard product not over 1

guidance SHIELDING/2 Containing Radio Signals

inch thick, complete with the fasteners and gaskets for installation. They shall be similar in design to those manufactured by Technical Wire Products, Inc., Cranford, NJ. The E-field attenuation characteristics shall be a minimum of 50 decibels from 10 kilohertz to 1 gigahertz. (132) C-2

Minimum attenuation levels--After the foil material is installed, the attenuation levels of the enclosure to external electric and magnetic fields shall not be less than those on the graphs presented in the figure.

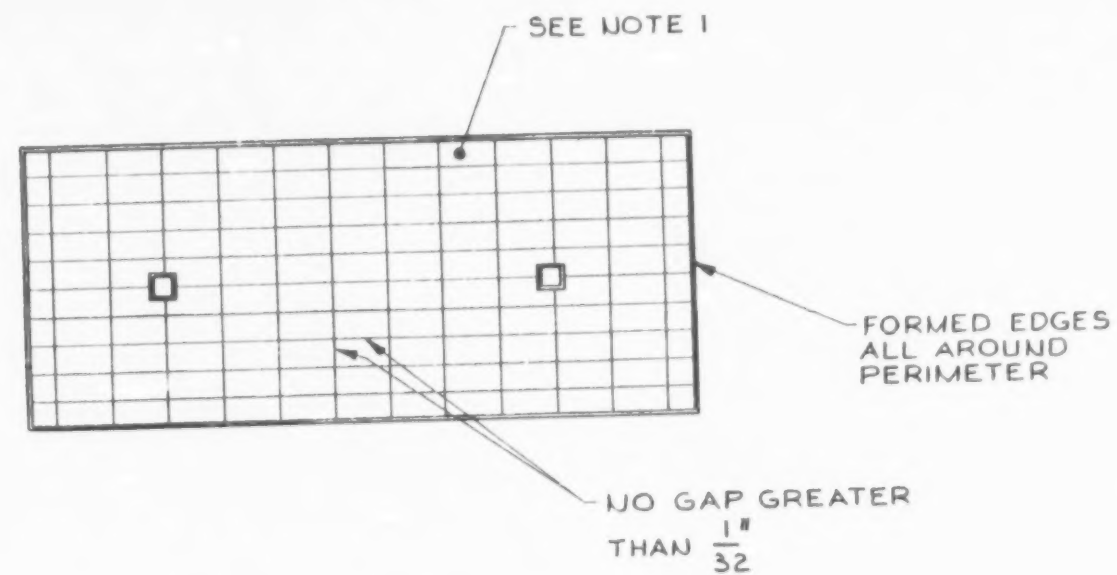
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NOTES:

1. ENTIRE AREA IS COVERED WITH CR STEEL SHEET, 4' X 8' X 1/16" THK. TURN STEEL SHEETS UP AT WALLS AND COLUMNS (IF APPLICABLE) AND FORM AS SHOWN BY DETAIL.
2. ALL STEEL SHEETS TO BE SPOT WELDED AT 12" INTERVALS WITH 2" MIN BEAD.

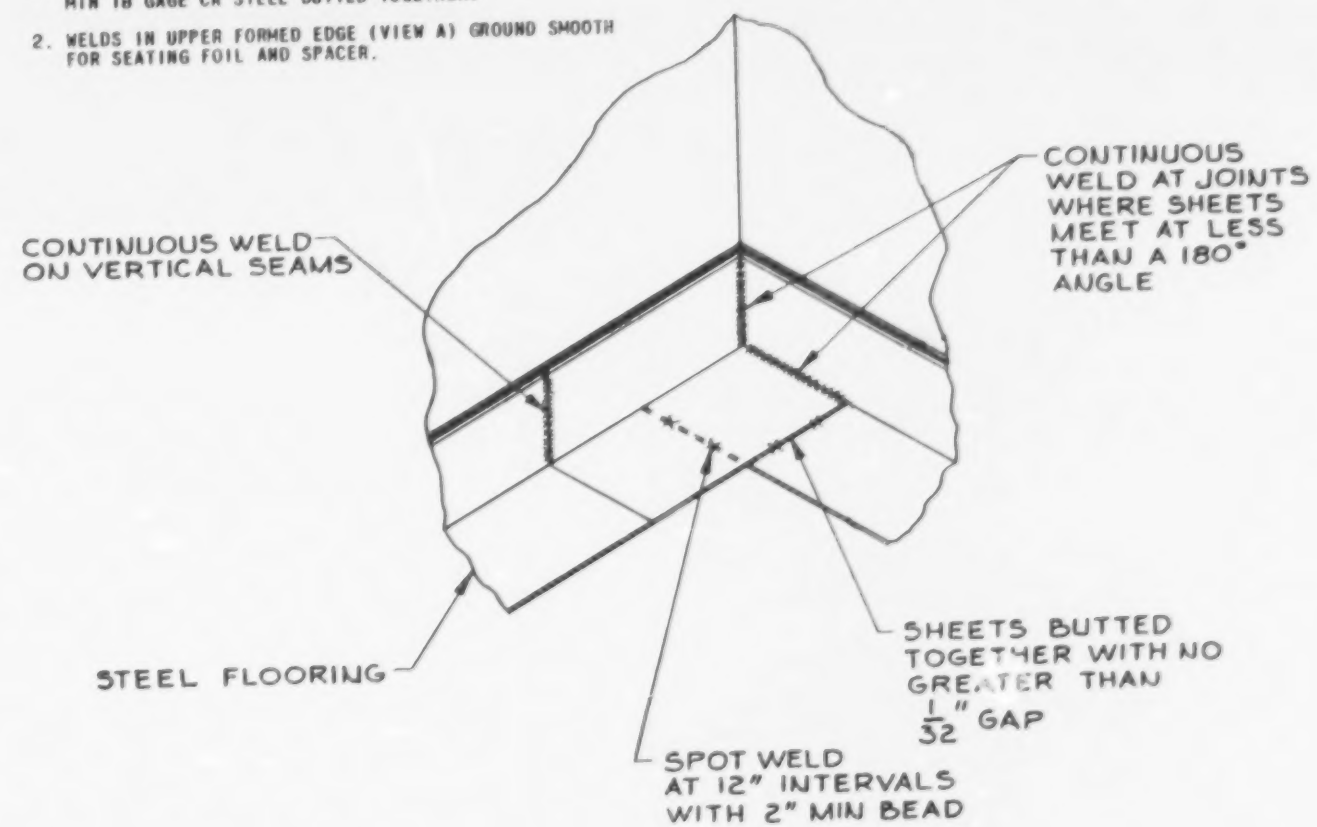


TYPICAL FLOOR PATTERN FOR STEEL SHEETS.

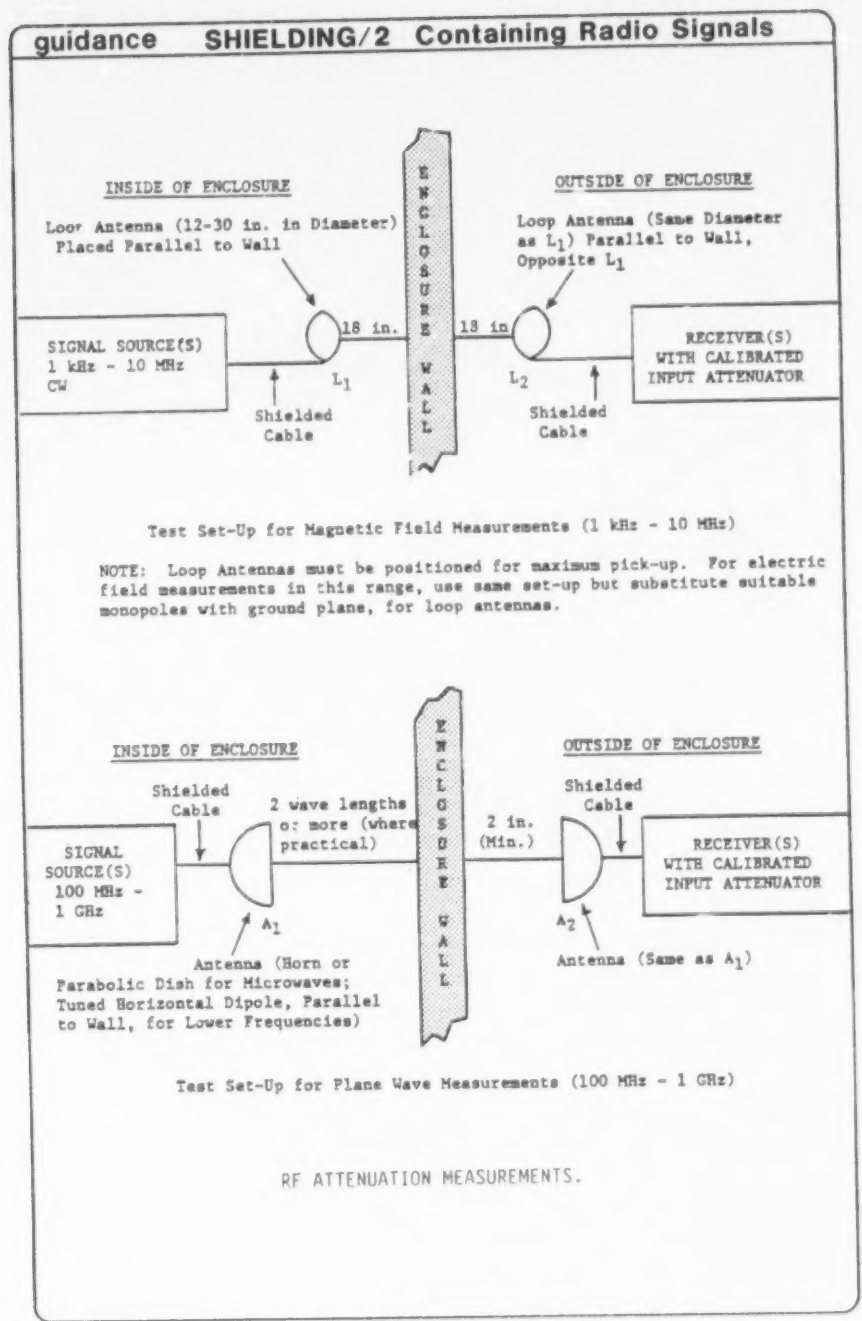
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NOTES:

1. STEEL FLOOR MADE OF SINGLE LAYER 4' X 8' SHEETS, MIN 18 GAGE CR STEEL BUTTED TOGETHER.
2. WELDS IN UPPER FORMED EDGE (VIEW A) GROUND SMOOTH FOR SEATING FOIL AND SPACER.



TYPICAL FLOOR SECTION.



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Structure (132) C-3

Size--The size and location of the enclosure shall be as specified in the contract.

Framework

Ceiling--The ceiling shall be made of sheets of 1/2-inch plywood. The plywood shall be installed and then predrilled in accordance with other room drawings. The drawings should show light and ceiling fixture locations, eliminating the need to drill through the foil covering when installing fixtures.

Walls--The enclosure walls shall be anchored to the walls of the existing room. The enclosure walls to support the shielding material shall be a flat surface of 1/2-inch plywood or a wood frame with studs at 20-inch centers. Flat cinder block room walls shall have 1- by 4-inch wood furring strips attached to 20-inch centers. A 2- by 4-inch wood stud frame shall be built or other types of room walls, such as metal or obstructed walls.

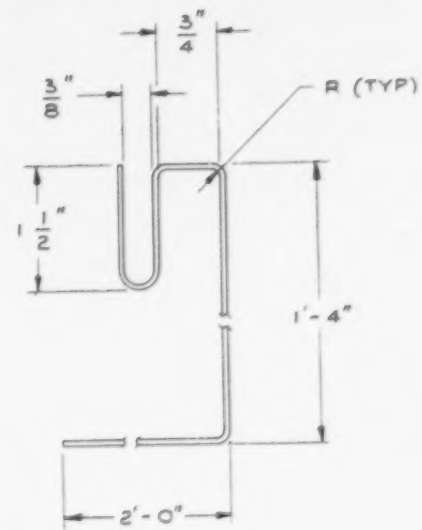
Floor--The enclosure floor shall have a layer of 18-gage steel sheets covering the existing room's floor. It should be attached to the foil on the walls as described here.

Entrances--The number of access doors and the direction of swing shall be as specified in the contract. Each entrance shall use a vestibule arrangement with two sets of doors (single or double) hung at right angles to each other. Doors shall be the solid metal fire type with metal frames.

Installation (132) C-4

Steel Floor--Steel sheets around the enclosed perimeter joining wall and floor shall be formed as shown in the figure entitled "Formed Steel Sheet for Floor" and placed on the floor and lower portion of the walls as shown in the figure entitled "Typical Floor Pattern for Steel Sheets." All sheet steel panels shall be butted together, with no gap greater than 1/32 inch, and welded at 12-inch intervals with minimum 2-inch beads. They shall be welded continuously along the seams that run vertically and on any seam where panels come together at other than 180° angle (see the figure entitled "Typical Floor Section"). Welds made along the upper formed edge shall be ground smooth to permit the steel space bars to be seated when the aluminum foil is joined to the formed steel wall section. Holes for securing screws may be drilled or punched. The formed sheet steel shall be attached to existing room walls with driven fasteners equipped with suitable washers.

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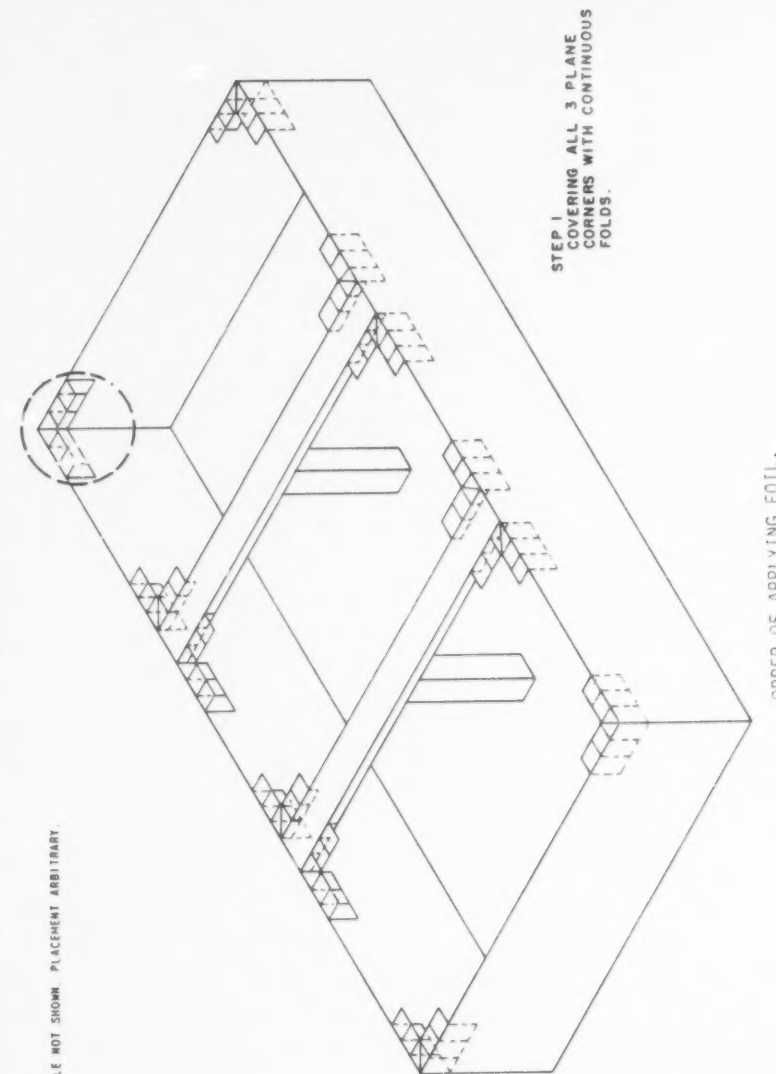


FORMED SHEET STEEL FOR FLOOR.

Aluminum foil--Two layers of aluminum foil shall be applied to the ceiling and four walls in the order and manner shown in the following six figures.

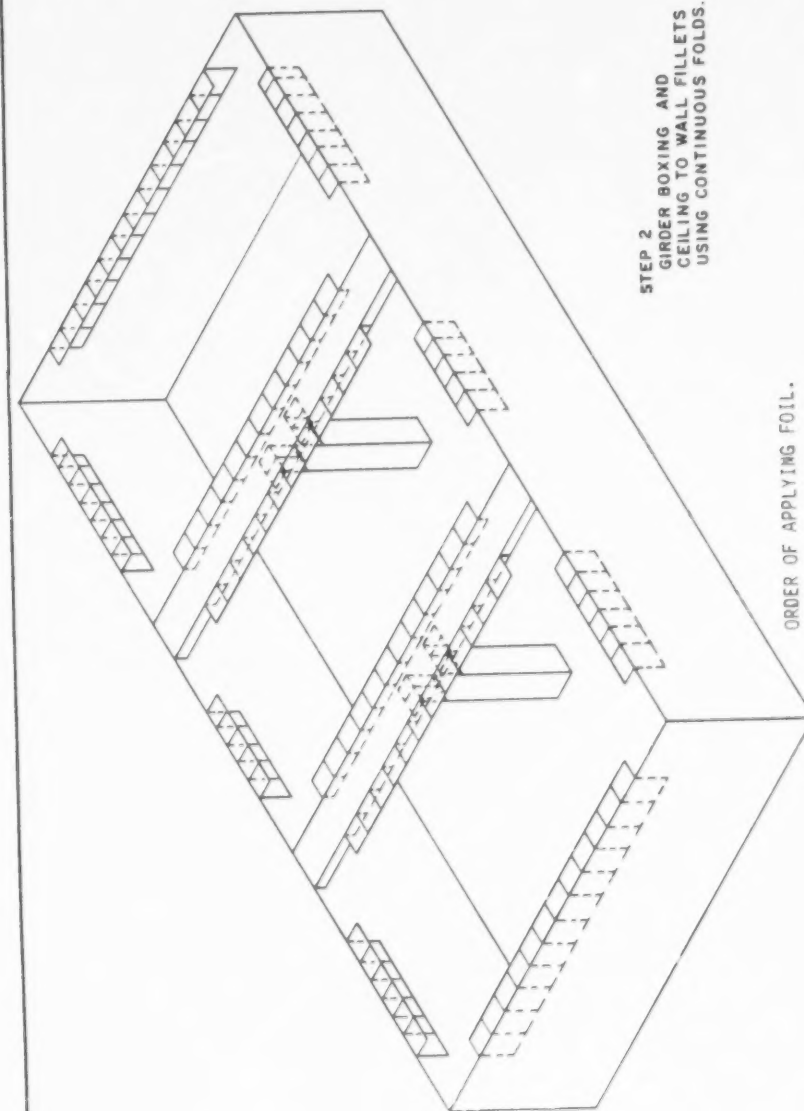
Corner heels--Corner heels shall be applied first as indicated using the same care and procedure indicated below. Corners shall have a continuous bend of foil rather than joint and formed as shown in the figure entitled "Typical Method of Folding Foil at Corner."

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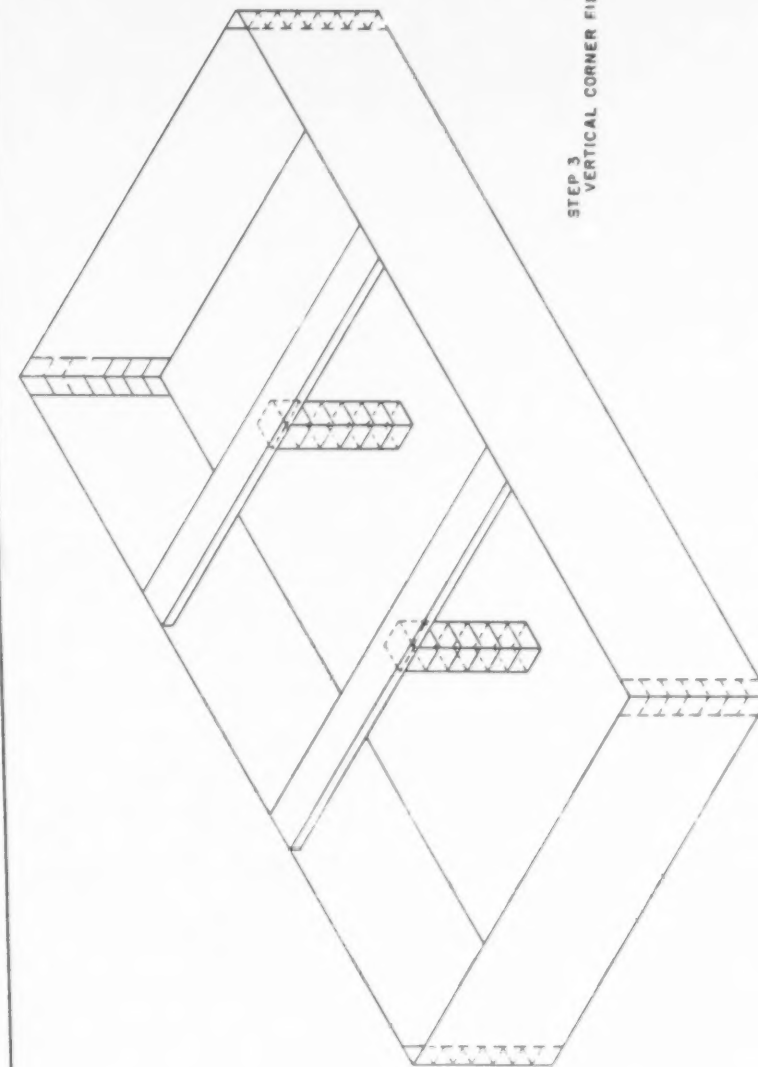


NOTES:
1. VESTIBULE NOT SHOWN PLACEMENT ARBITRARY.

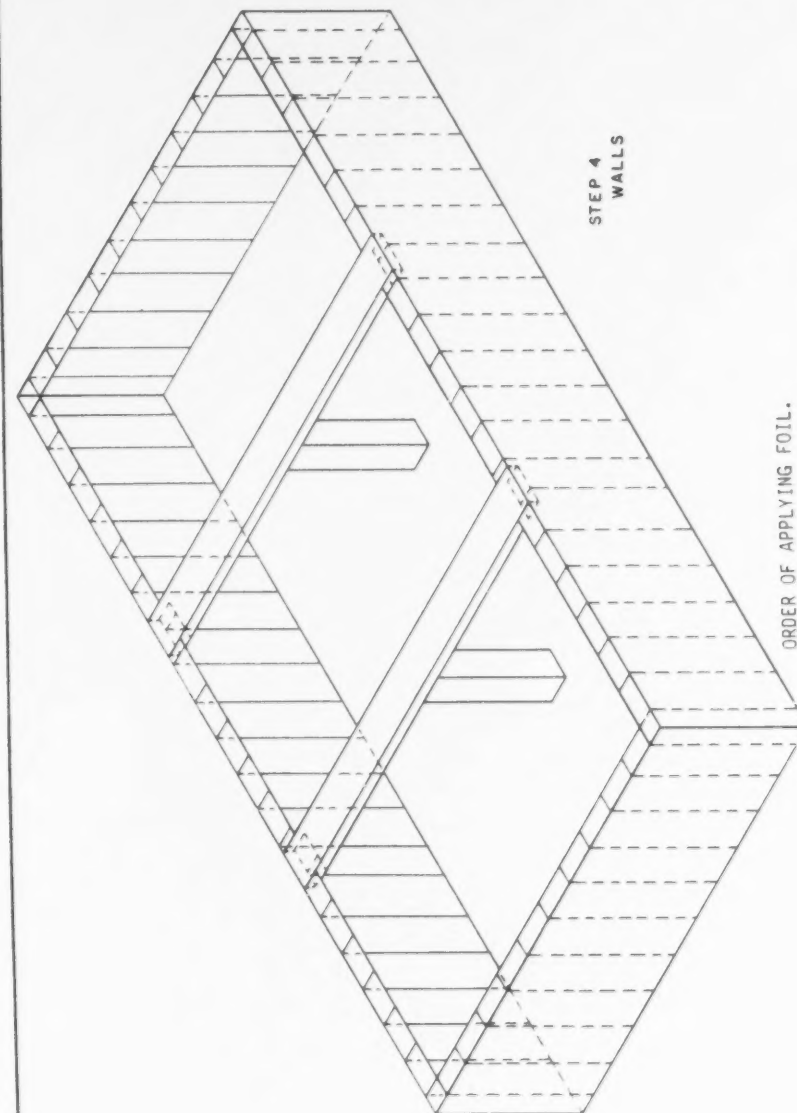
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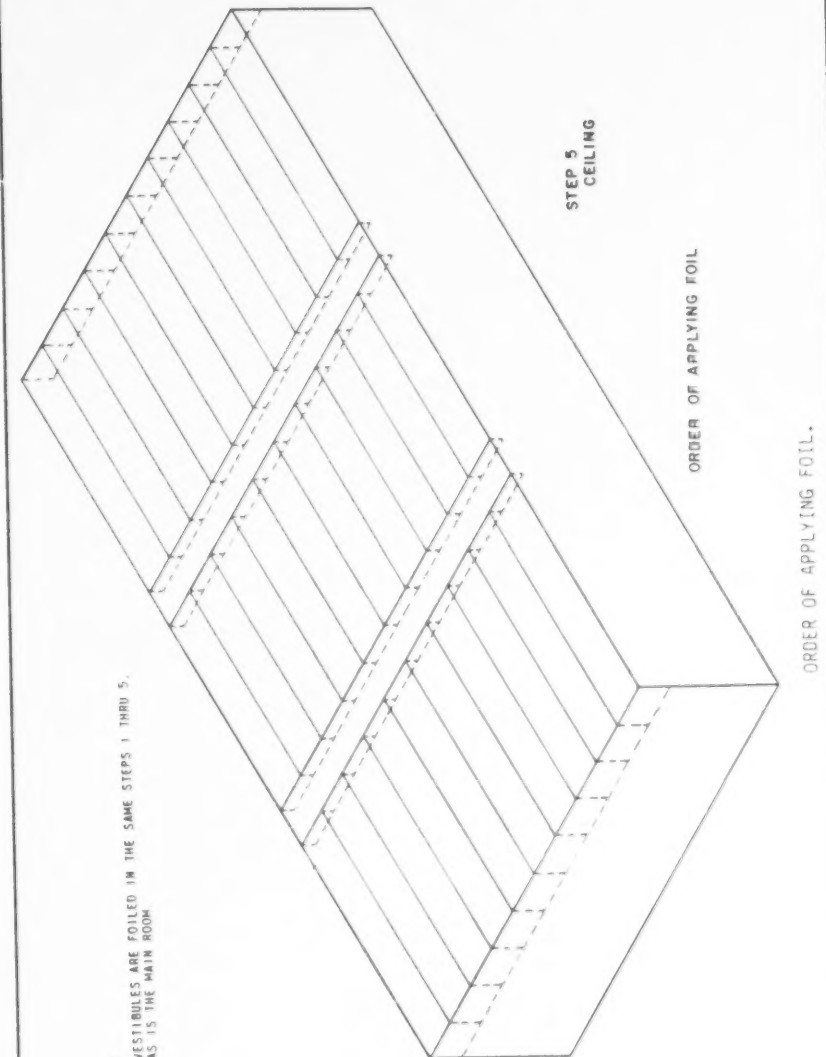
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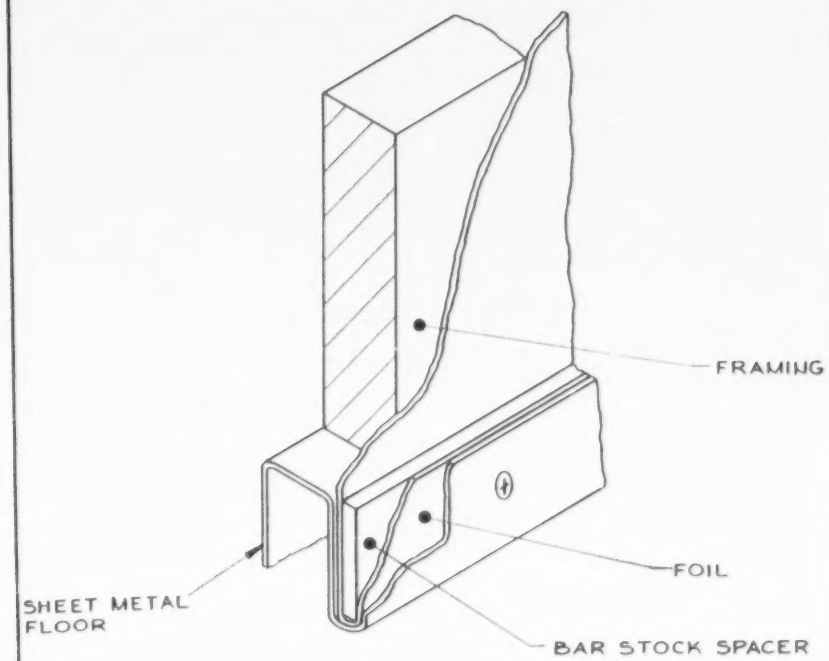


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NOTES:
1. VESTIBULES ARE FOILED IN THE SAME STEPS 1 THRU 5.
AS IS THE MAIN ROOM.

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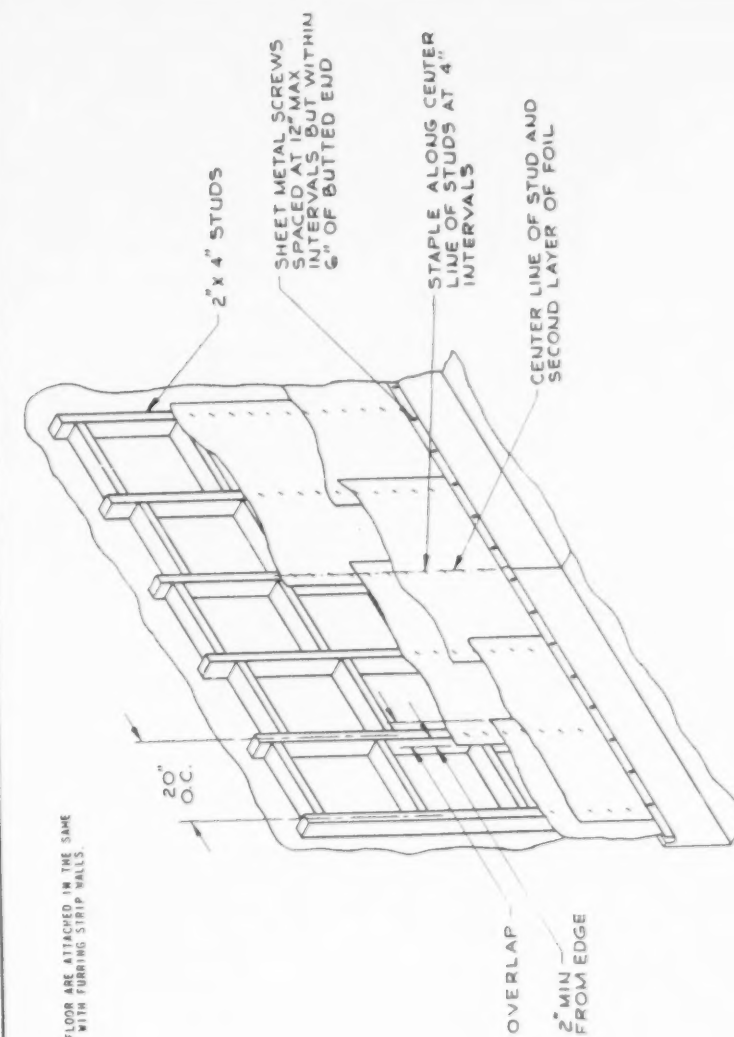


FOIL APPLICATION.

NOTES:

1. APPLY FOIL IN STEPS AS SHOWN.
2. APPLY FOIL IN CONTINUOUS UNBROKEN SHEETS TO CONFORM TO PATTERNS FOR WALLS WITH FURRING STRIPS AND STUDS.
3. USE SAME TYPE PATTERN AS SHOWN FOR FOIL COVERING WALL AND CEILING OF PLYWOOD.
4. FASTEN FOIL WITH STAPLES AS DESCRIBED.
5. USE 1 1/2" X 3/16" BAR STOCK TO ATTACH FOIL AND STEEL FLOOR IN MANNER SHOWN. STOCK PIECES ARE BUTTED TOGETHER, NOT WELDED. SHEET METAL SCREWS THREADED THROUGH OUTSIDE CHANNEL AND FOIL. TIGHTEN SCREWS TO FORCE SPACER AGAINST FOIL AGAINST BACK OF CHANNEL.
6. SHEET METAL SCREWS SPACED A MAXIMUM OF 12" INTERVAL BUT A MAXIMUM OF 6" FROM END OF EACH BAR STOCK.

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FOIL APPLICATION ON WALLS WITH STUDS.

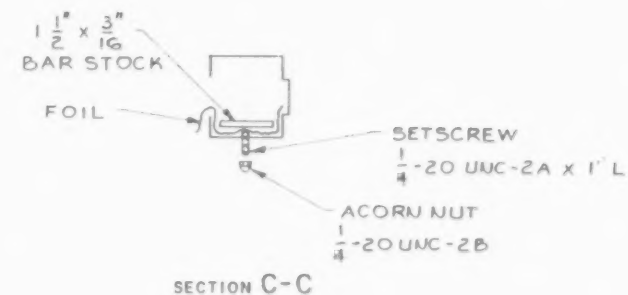
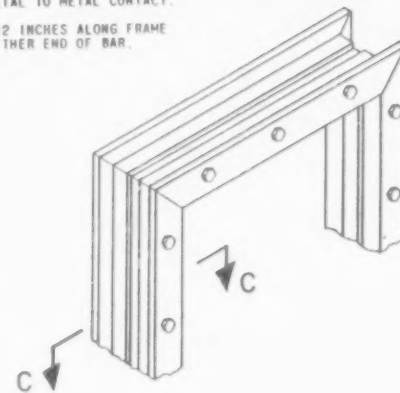
NOTES:

1. FOIL AND FLOOR ARE ATTACHED IN THE SAME MANNER AS WITH FURRING STRIP WALLS.

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NOTES:

1. SANDWICH FOIL BETWEEN BAR STOCK AND METAL FRAME AND TIGHTEN SCREWS.
2. CONTACT AREA BETWEEN FOIL AND FRAME SHOULD BE FREE OF PAINT FOR METAL TO METAL CONTACT.
3. SPACE SETSCREWS EVERY 12 INCHES ALONG FRAME AND WITH 6 INCHES OF EITHER END OF BAR.



STANDARD METAL DOOR FRAME.

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Penetrations (132) C-5

Water pipe--Foil panels adjacent to openings for pipes or conduit shall project at least 2 inches into the opening to provide fold-over flanges for installation of pipes and conduit. A typical pipe installation is given in the figure below entitled "Typical Pipe Penetration Through Wall." At the point where the pipe leaves the foil enclosure, a nonmetallic (non-conductive) pipe section with a minimum length of 6 inches shall be installed.

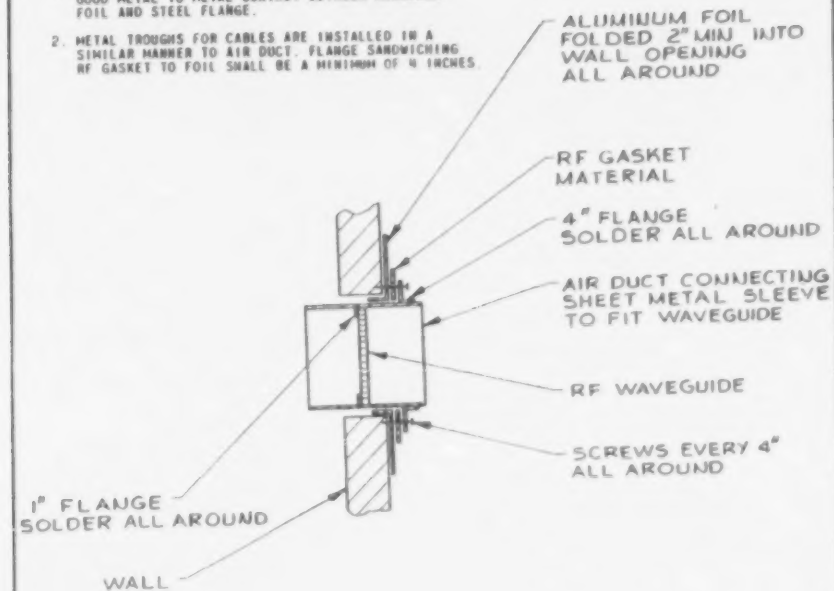
Air ducts--Foil panels adjacent to openings for air ducts shall project at least 2 inches into the opening, cut and turned into the opening. Waveguides shall be installed in the wall within an 18-gage steel sleeve which shall be connected to the fresh air intake or exhaust duct. A typical installation is indicated on the figure entitled "Air Duct Waveguide Installation." A 4-inch flange on the sleeve shall make positive contact with the aluminum foil around the opening. Where it leaves the enclosure, the duct shall be attached to a nonconductive duct section with a minimum length of 6 inches. The nonconductive section shall then be connected with the remaining ductwork in the system.

Facilities--Ceiling fixtures such as lights and suspended ceilings shall be installed using the predrilled holes in the plywood ceiling. The holes shall be located, and the foil cut and pushed into the hole. Care should be taken not to rip more than 1/2 inch from the hole. Any anchoring bolt shall be inserted with a 16-gage steel washer into the hole and drawn tight against the foil with a nut and lock washer to form a good seal. Other fixtures, a.c. power, telephone and signal terminals, and their associated interconnecting cables shall be entirely contained within the enclosure. All lines shall penetrate the enclosure only at the service panels.

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NOTES:

1. RF GASKET MATERIAL MAY BE WIRE MESH. INSURE GOOD METAL TO METAL CONTACT BETWEEN ALUMINUM FOIL AND STEEL FLANGE.
2. METAL TROUGHS FOR CABLES ARE INSTALLED IN A SIMILAR MANNER TO AIR DUCT. FLANGE SANDWICHING RF GASKET TO FOIL SHALL BE A MINIMUM OF 4 INCHES.

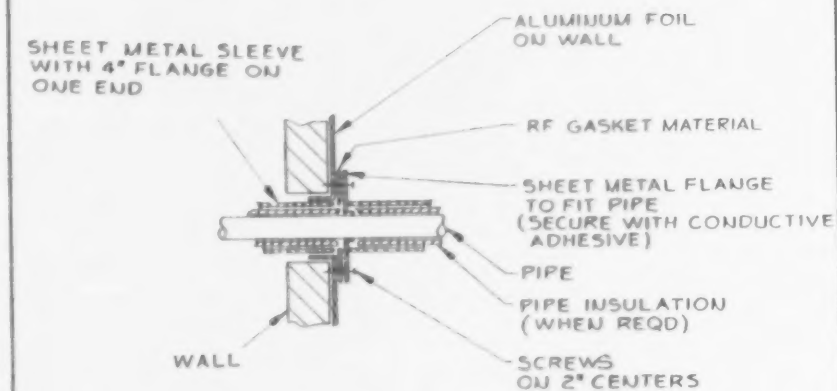


AIR DUCT WAVEGUIDE INSTALLATION.

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NOTES:

1. RF GASKET MATERIAL MAY BE WIRE MESH. INSURE GOOD METAL TO METAL CONTACT BETWEEN ALUMINUM FOIL AND STEEL FLANGE.
2. USE CONDUCTIVE ADHESIVE TO SECURE METAL FLANGE TO PIPE PENETRATIONS. CHECK FOR ADEQUATE TEMPERATURE CHARACTERISTICS.



TYPICAL PIPE PENETRATION THROUGH WALL.

Electrical (132) C-5

Filter mounting--A filter shall be provided for each incoming power, telephone, and signal line penetrating the enclosure. All filters shall be mounted at service entrance panels. Each service entrance panel shall be made of aluminum of sufficient gage to support necessary filters; the panel shall be attached to the wall of the enclosure. A hole shall be cut in the wall and foil allowing for a 4-inch flange to be folded over into the opening. The panel shall be mounted on the outside of the room, attached to the wall with screw fasteners spaced every 4 inches, and tightened. To insure a good seal against the foil flange, an RF gasket shall be placed between the panel and foil. Care should be taken when mounting the filters that a good electrical bond exists between the filters and the panel.

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Characteristics--All filters shall provide a minimum of 50 decibels of insertion loss from 14 kilohertz to 1 gigahertz, measured under full load in accordance with MIL-STD 220. Filters shall be designed to carry the primary voltage and current specified in the contract.

Grounding--The enclosure itself shall be connected to earth ground. A 2/0 gage cable shall be connected between the steel panel floor and grounding plane in the earth. When an earth ground is not feasible, materials for connection to a.c. ground outside the enclosure shall be furnished. The grounding cable shall be connected to the steel floor in the manner shown for shielded wires in the figure entitled "Shield Ground Point." The procedure for grounding equipment and cable shielding shall be as shown in the figure entitled "Equipment Ground Point."

a.c. power requirements--The a.c. power requirements shall be as specified in the contract.

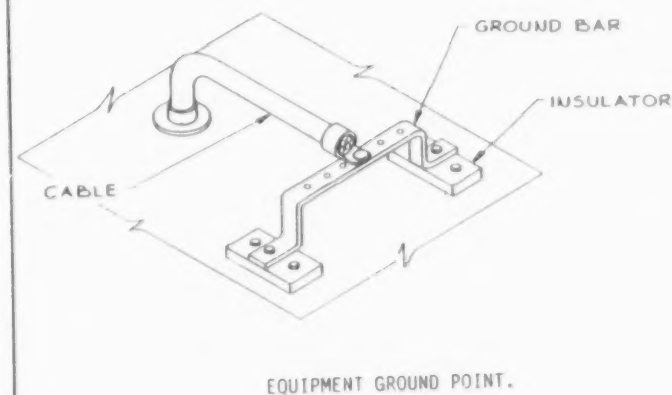
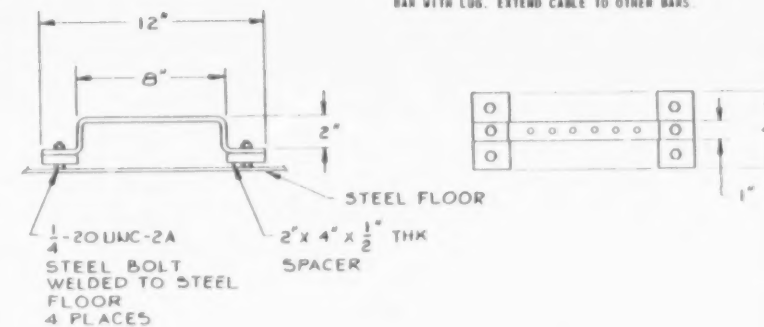
Lighting requirements--The lighting requirements shall be as specified in the contract.

Air-conditioning requirements--Air-conditioning requirements shall be as specified in the contract. Internal ductwork and waveguides shall be supplied by the contractor and installed in a manner described in B10b of reference 132.

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NOTES:

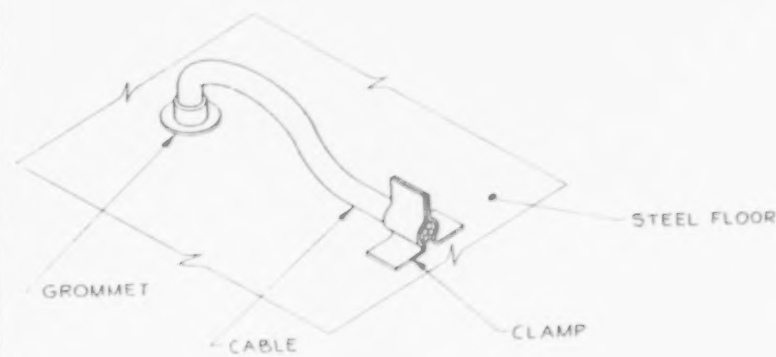
1. INSTALL INSULATED 8 INCH BRASS BAR, 1/4 INCH THK WITH SIX 1/8 INCH DIAMETER HOLES. WELD GROMMET TO STEEL FLOOR. FEED EXISTING CABLE THRU GROMMET AND SECURE TO BAR WITH LUG. EXTEND CABLE TO OTHER BARS.



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NOTES:

1. WELD CABLE CLAMP AND GROMMET TO STEEL FLOOR SHEET. SECURE EXISTING GROUND CABLE TO CLAMP AND SPACE CONNECTION.



SHIELD GROUND POINT.

Workmanship--The enclosure, including all facilities, parts, and accessories, shall be constructed, finished, and installed in a thoroughly workmanlike manner, shall be free from defects which may affect appearance or serviceability, and shall conform to applicable specifications, standards, and drawings. Installation shall be so conducted as to avoid damage to other surfaces and to public and private property in the area. Any such damage shall be the responsibility of the contractor. (132) C-6

Site preparation--When considering an enclosure installation, a few basic preliminary precautions can minimize the construction problems and maximize the protection capabilities.

Room design--Additional protection from an enclosure can be achieved by proper placement within the parent room.

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Door placement--Since the enclosure door is potentially the weakest point, and is in fact the weakest point for foil enclosures, orient the enclosure so that the door faces the most secure area (toward the center of the controlled area). This will minimize the risk from any leakage during opening or closing, or due to improper sealing.

Minimal penetrations--When possible, locate the enclosure so as to minimize penetrations by pipes or ducts. If possible, reroute piping and ducting around the enclosure rather than through it.

Wall spacing--Enclosures, except for foil ones, should be placed at least 18 inches from the parent room walls to facilitate inspections. If an 18-inch separation is impracticable due to limited space, the separation could be smaller--provided that clandestine probing or penetrations of the enclosure is not a possibility. (132) 5-3

Construction precautions

Floor support--Determine the load limits of the parent room floors to be sure that the existing structure will support the enclosure load adequately.

Roof support--One source of leakage from armored plywood and foil rooms is sagging roof panels, especially roofs that support heavy equipment such as air-conditioners. When constructing an enclosure, take care that the roof panels are sufficiently supported that they will not sag.

Doors--Especially critical in high-quality enclosures are sturdy door frames, doors, and hinges that avoid sagging and prevent open seams. A closing mechanism that provides sealing pressure at least three points is necessary to seal adequately with finger stock.

Penetrations--Such enclosure penetrations as ventilation ductwork, chilled water pipelines, and conduit, are unavoidable and must be installed carefully. The goal is to electrically isolate the metallic structure passing through the enclosure walls so that it will not act as a fortuitous conductor. The structure is isolated by inserting a nonconductive pipe or duct section of approximately 6 inches into the exterior wall surface. This procedure is crucial for high-quality enclosures. The metallic piping or duct within the enclosure should be bonded to the enclosure wall surface. RF waveguide material must be phased in air ducts, vent openings, and chilled water pipes to eliminate radiation through these openings. (132) 5-3

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Maintenance--Enclosures must be tested, inspected, and maintained periodically during operational use. The frequency of inspections will depend on the extent of use. A suggested inspection schedule is presented for enclosures based on their usage. Maintenance should be performed as required.

Daily--Doors with finger stock used more than 10 times a day.

Weekly--Doors with finger stock used less than 10 times a day.

Monthly--Filters, air ducts, and motor-generator (if used).

Annually--All of the above, plus joints, panels, and roof. Leakage tests should be included. (132) 5-3

Inspections and maintenance of all enclosures are necessary to detect and eliminate deteriorated shielding effectiveness. Doors used with a quality enclosure in high-traffic areas require close inspections for corroded or damaged surfaces. After an enclosure settles in its foundation, seams may loosen and cause signal emission leaks. After the first shielding effectiveness test, a leakage test should be scheduled periodically on all types of enclosures. Whenever filters are changed, inspect them for good electrical connections between their case and enclosure wall. Also look for cracks or loose lids on the filter case. The necessary maintenance work for each type of enclosure will differ in amount and frequency. (132) 3-3

Door and frame maintenance (132) 5-4

Cleaning--The contact surfaces of doors and frames should be cleaned with steel wool to remove all traces of corrosion, floor wax, or other nonconducting material. Care must be taken to avoid deforming the finger stock.

Finger stock--Bent or deformed finger stock may be restored to its original shape with a wide-blade screwdriver, a flat piece of rigid metal, or long-nose pliers. Care should be taken to avoid deforming fingers next to those being adjusted. Broken fingers should be cut away from the door with sheet metal shears. Replacements may then be soldered into place.

Latch and lock

- If the door is hard to close and the striker plate or latch shows excessive wear, the position of the striker plate should be adjusted.

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- If the enclosure door has a built-in lock, and if RF checks reveal leakage around it, the knit-metal gasket around the shaft should be replaced.
- If the door cannot be repaired by the techniques described above, the enclosure manufacturer should be notified.

Scored doorframe--Deep dents in the doorframe, caused by attempts to close the door with the latches protruding, may be prevented by attaching brass plates to the face of the doorframe. Dents on the contact surface may be filled with solder and sanded flat.

Sagging door--If the door scrapes its frame during normal operation, or if the depth of the contact pattern is irregular, the door may be sagging. If the hinges are intact the door position may be adjusted by loosening the hinge screws, shifting the door to its proper position, and retightening the screws. If the hinges are worn badly, they should be replaced with steel hinges.

Acoustic seal--Acoustic leakage around the door may be caused by a worn or broken acoustic gasket, by misalignment of the door, or by unintentional metal-to-metal contact between the door and its frame. Design details of acoustic seals vary by manufacturer, but they generally include adjustable framing strips and rubber gaskets. Worn, flattened or torn gaskets should be removed, and replacements glued to the door. Framing strips should be adjusted only as a last resort, since alignment is critical.

Inspection--During construction of an enclosure, close inspection should be done to eliminate substandard work, loose seams, poor metal-to-metal contact, or improper filter installations, all of which could sharply reduce the shielding effectiveness of the enclosure. Inspections should take place before a final wall covering is applied to the shielding, which will make it inaccessible. Inspections must be made at reasonable intervals after enclosure installation to correct any leaks and to insure that the enclosure will continue to provide maximum protection. (132) 3-4

For any type of enclosure, some trouble spots can be located quickly by closing the enclosure door and turning off the lights inside with the outside lights on. Check the seams, corners, door filter panels and other penetrations for light leaks. Any light leak may also leak RF. (An exception is the waveguide air grille.) However, all RF leaks may not produce light leaks. Apply the following additional inspection procedures to the appropriate type of enclosure. (132) 3-4

Air duct cleaning--Frequent cleaning or replacement of the

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air filter in the air-conditioner prevents clogging of the waveguide air vents. A vacuum cleaner and an aerosol grease solvent should be used to clean these vents. The vents should not be removed from the shield, since reinstallation with a good RF joint is difficult. (132) 5-4

Repair of acoustic ducts--Acoustic leakage from acoustic ducts is usually caused by unintentional contact between metal ductwork and the RF shield, or by sagging ducts which compress the acoustic gaskets. Holes or worn spots, particularly in nonmetallic parts, also cause leaks. Repair techniques are usually self-evident. (132) 5-4

Major structural repairs--Loose joints in bolted enclosures, detected during RF leakage tests, can be tightened with a torque wrench. For inside bolted enclosures, this requires removing all interior materials which cover the leaking joint. Any acoustic materials must be carefully reinstalled to prevent subsequent acoustic leakage. Major structural failure, such as a sagging roof, warped panels, or deformation of the floor, should be repaired by the enclosure manufacturer. Torn foil panels should be replaced or patched. If a tear occurs in a panel covering plywood or other solid surface, a patch may be applied by using a conductive adhesive mastic around the tear and placing a patch of foil which covers the hole or tear completely and extends beyond it by at least 4 inches. When a tear occurs between studs or fir strips, the panel should either be replaced or an additional foil panel should be installed on top of the torn section, making a third layer of that particular section. (132) 5-4

Sources of shielded enclosures--A number of commercial firms manufacture several types of shielded enclosures. These firms also make enclosure parts such as doors, filters, and waveguide grills. Several are listed below. This listing should not be considered an endorsement by the NSA of any or all of these firms, nor should it be regarded as complete. (132) 5-4

- Ray Proof Corp., Norwalk, CT--Armored plywood.
- ARK Electronics Corp., Willow Grove, PA--Steel rooms.
- All-Shielded Enclosures, Inc., Westbury, NY--Steel rooms.
- Total Spectrum Engineering Corp., Huntington Beach, CA--Steel rooms.
- Universal Shielding Corp., Plainville, NY--Steel rooms.

guidance SHIELDING/2 Containing Radio Signals**C. Isolators and filters****Background**

Conducted C-E on signal, control, or power lines may originate in a piece of equipment or be coupled onto a line when that line passes through a strong electromagnetic field. Filters are the common countermeasures used to reduce or eliminate conducted C-E from black conductors. In order to work effectively, a filter must be well grounded to the C-E signal source reference. The frame of a shielded enclosure provides a good electrical ground needed for a filter. A filter mounted on an enclosure eliminates the possible escape path for C-E coupling onto conductors when the conductors must penetrate the shield. Also available are optical isolators that provide a high degree of electrical isolation. These devices prohibit conduction of C-E signals out of an enclosure by means of a nonconductive optical link. Isolators are more expensive than filters but they provide more isolation with fewer installation problems. (132) 4-1

Considering only shielding requirements while ignoring filter/isolator requirements is self-defeating. A good shielded enclosure can be neutralized by failure to filter/isolate lines penetrating the shield since a radiated signal within may couple onto lines and be conducted outside the shielded enclosure. The amount of filter/isolation attenuation needed will depend largely on the degree of shielding required for radiated signals. Since radiated fields couple onto signal lines and signal lines radiate, the amount of conducted signal attenuation should be based on the amount of radiated signal attenuation. (133) 0-2

Filters (132) 4-1

Low-pass filters--Low-pass filters allow intended signals on a conductor to pass while attenuating the higher frequency unintended C-E signals. Low-pass filters are used with shielded enclosures for power lines, and with control and signal lines which penetrate the shield. The amount of attenuation a low-pass enclosure filter provides for conducted signals should be in the same magnitude and frequency range as the enclosure provides for radiated signals. Specifically, both solid steel and armored plywood enclosures would need 100 decibels attenuation filters up to a frequency of 10 gigahertz and aluminum foil enclosures need a 50 decibel or greater attenuation filter up to a frequency of 1 gigahertz.

Attenuation--The conducted attenuation provided by an enclosure filter should have the same magnitude as the RF attenuation provided by the enclosure. A 100 decibel RF shielded enclosure requires a 100 decibel signal or power line filter. A 50 decibel foil enclosure requires at least a 50 decibel filter. Some special cases may call for higher attenuation requirements; these can be decided on a case-by-case basis.

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Power rating--The filters used in an enclosure must have sufficient power ratings to handle the current demands for the entire installation, including lights and system equipment. Excessive current draw on low-power-rated filters may degrade the filter's attenuation characteristics. When ordering filters, consider both present and future power requirements.

Installation--Regardless of a filter's attenuation rating, it cannot achieve full attenuating properties without a proper ground connection. A filter's case must be completely bonded electrically to the enclosure's metal surface for optimum results.

Replacing defective filters--Excessive voltage drop, overheating, and leakage are the most common signs of defective filters. The manufacturer should repair filters made locally. After removal of the defective filters, the feed-through connectors on the panel should be cleaned with steel wool. The new filters should then be installed carefully to insure good RF continuity between them and the panel. If the filters are equipped with lids, the lip of each lid and the corresponding surface of the filter case must be flat, free from scratches, and cleaned with steel wool. Soldering the lid to the case insures a good RF joint, but the manufacturer should first be asked whether the soldering heat will damage the filter.

Repair of RF leakage--RF leakage at the filter panel is usually caused by corrosion at the junction between each filter and the panel, or between the lid and filter case. Either problem may be corrected by cleaning the contact surfaces with steel wool and reinstalling the filters.

Repair of acoustic leakage--Acoustic leakage at the filter panel is usually caused by unintentional metal-to-metal contact between the acoustic filter cover and the outer shield. Replacement of acoustic gaskets between the metal surfaces should correct the problem.

Isolators (132) 4-2

Analog--Analog isolators are one alternative to telephone line filters. The isolators can provide 100 decibels or more isolation outside the audio frequency range. An isolator consists of a send/receive unit coupled to a fiber optic transmission line whose far end is also coupled to another send/receive device. The sending unit converts electrical energy into light energy and then transmits it down the fiber. The receiving device converts the light back to electrical energy. The send/receive devices are installed on the inside and outside of an enclosure. The fiber is then passed through the wall of the enclosure in a waveguide opening. (132) 4-2

guidance SHIELDING/2 Containing Radio Signals

Digital--Digital isolators also provide 100 decibels or more isolation for digital signals from d.c. to 6.3 MB/s. The digital isolator will pass only the intended digital signal while blocking any coupled digital energy from other devices.

Optical--If administrative telephones must be used within the shielded enclosure, optical isolators should be used where the telephone line passes through the enclosure walls. The optical isolators should be approved by the cognizant engineering activity before installation. (133) 0-2 However, the use of administrative telephones is discouraged.

Sources of filters and isolators--A number of electronic firms manufacture several different types of filters and isolators. A few of these firms are listed below. The listing should not be considered an endorsement of any or all of these firms, nor should the list be regarded as complete.

- Erie Technological Products, Inc.
644 West 12th Street
Erie, PA 16513
- Filtron Manufacturing Co., Inc.
6 Aerial Way
Syosset, NY 11791
- RF Interonics
100 Pine Aire Drive
Bay Shore, NY 11706
- Sprague Electric Co.
97 Marshall Street
North Adams, MA 01247
- Versitron, Inc.
6310 Chillum Place NW
Washington, DC 20011

DCA CIRCULAR 300-95-1

4-66

guidance

guidance

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**SB5
EMP / HEMP Protection**

References

- 15b. Military Handbook (MIL-HDBK)-419, Grounding, Bonding, and Shielding for Electronic Equipments and Facilities (U.S. Department of Defense, 1 July 1981).
16. Design Practices for High Altitude Electromagnetic Pulse (HEMP) Protection (Defense Communications Agency, June 1981).
17. EMI Design, 1980.
24. Systems Engineering Specification 77-4 (Air Force Communications Command, 1842 EE9 SES 77-4, Jan 1980).
120. EMP Engineering Practices Handbook, NATO File No. 1460-2 (Oct 1977).
188. Communication Facility Design Practices for Protection Against High-Altitude Electromagnetic Pulse (Harry Diamond Laboratories, Adelphi, MD, July 1984).

SB5 EMP/HEMP PROTECTION

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EMP/HEMP

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function

Electromagnetic pulse/high-altitude electromagnetic pulse (EMP/HEMP) protective measures are based on intercepting the incident energy and dissipating it or reflecting it away from the threatened device, equipment, or facility. (15b) 1-186

policy/sop

1. The handbook Defense Switched Network Design Practices for Protection Against High-Altitude Electromagnetic Pulse (ref 16) establishes mandatory design practices for the Defense Switched Network (DSN). The purpose is for the DSN to continue to exist and to function without interruption when it is subjected to the HEMP produced by nuclear detonations. The handbook applies to all new acquisitions. It also shall be consulted when HEMP requirements are included for equipment, components, spaces, facility envelope, and site in the categories of shielding, isolation, transient suppression, common-mode rejection (CMR), and grounding. (16) 9

2. Another significant reference related to facility HEMP protection is Communications Facility Design Practices for Protection Against High-Altitude Electromagnetic Pulse, July 1984 (ref 188). This document provides design practices to mitigate the effects of HEMP on telecommunication facilities. It closely follows the methodology and practices found in reference 16, which was prepared for the Defense Communications Agency (DCA). However, it differs from this document in several ways. First, the document's design practices are not directed at transportable communication elements. The site housing is considered integral to the HEMP immunity approach and has a hardness allocation. By not considering transportability, the practices formerly applied to components and spaces are less complex. Second, the document applies to both new and retrofit facilities. Third, the practices contained in the document have been updated based on new technical findings and practical engineering construction.

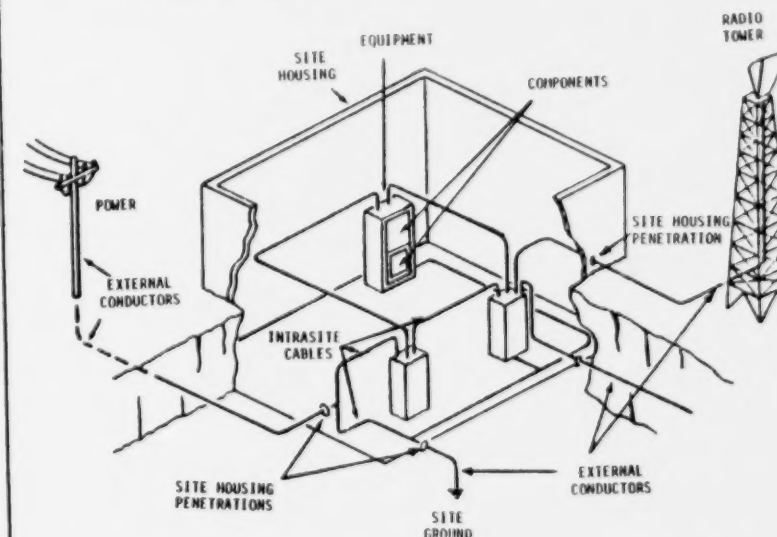
3. This chapter integrates both references in discussing the protection effectiveness rationale, protection category definitions, and functional definitions.

In buildings, the plant's external environment (site--zone 0) is separated from the internal intrasite environment (spaces--zone 1) by the building's metallic structure (shield 1). The cabinet walls (shield 2) and the cabinet environment (zone 2, etc.) can then be used to construct the shielding topology shown in the first figure. In this topology, the more interference-free environments are identified by larger zone numbers and have a greater number of shields between them and the external environment. Ideally, the shields are continuous, closed, and highly conducting Faraday types; in practice, they may be compromised by penetrating conductors (penetrators) or apertures. For

policy/sop

example, an insulated conductor penetrating shield 1 will carry a large zone 0 current through the shield into zone 1 unless it is treated with limiters and filters at the penetration point, as the first figure shows. Zone barriers may have similar violations between higher numbered zones. Thus, a conductor (e.g., ground) entering a cabinet may carry intrasite level (spaces--zone 1) interference into the small-signal (zone 2) circuits unless interference-limiting procedures are applied at the cabinet entry point. (188)

Zonal philosophy--Communications facilities (next figure) contain several regions of electromagnetic (EM) environments separated by barriers such as building walls and cabinet shields. For example, the building walls separate the harsh external environment from the more protected room environment, and the equipment cabinet separates the room environment from the small-signal environment inside the cabinet. Within the cabinet, there may be a third level of shielding to separate the ambient small-signal environment from particularly sensitive components such as radio frequency (RF) amplifier input stages or other low-noise stages. A shielding and grounding topology can be constructed such as that illustrated in the second figure, in which these naturally shielded regions are represented by zones of progressive isolation separated by EM barriers (shields). Here, for simplicity, a.c. power is shown being led directly to the equipment. For most telecommunications facilities, however, the equipment is powered by d.c. batteries kept charged by converted a.c. (188)



TYPICAL COMMUNICATIONS FACILITY. (188)

policy/sop

EMP protection philosophy is based on protection against three environmental effects: ground currents, magnetic fields, and electric fields. For ground currents, it is important to control the path that can be collected by water pipe, conduit, or other conductive materials entering a facility or a structure. This must be done without creating objectionable electric fields due to discontinuities or penetrations of such conductors. To protect electrical wiring and components from magnetic and electric fields, some type of shield must be used and must surround the items to be protected. (24) B-1

These measures are taken by providing adequate metal shielding around the facility (or the equipment inside); by installing fast-response surge arresters on power, signal, and control lines; by terminating the shields and arresters in an earth connection offering a low impedance; by carefully controlling the points of penetration of collectors; and by paying particular attention to all bonds throughout the protective system. (15b) 1-186

Common-mode rejection design practices are not required for in-house elements. Using balanced inputs and outputs to equipment, however, provides an additional measure of protection. Common-mode rejection design practices are used on exterior elements such as the facility transformer (see a.c. power) and signal, control, and antenna cables. (See guidance.) (16) 75

Hardening process and logic flow--HEMP hardening of a component, a piece of equipment, or a facility consists mainly of establishing zone boundaries or surfaces through which HEMP energy must pass to reach sensitive electronics. The energy can pass through these zone boundaries by field diffusion and by conducted transients. The successive boundaries' effectiveness must be great enough to reduce the transmitted energy to tolerable levels. Conductors that penetrate these zone boundaries must be treated in a way consistent with the shielding effectiveness of the boundary itself. (188)

Application of zonal philosophy--In using this philosophy, certain zones and boundaries have been delineated. These regions have been characterized into five elements, with their relationship to the zone boundaries as follows (in order of importance): (188)

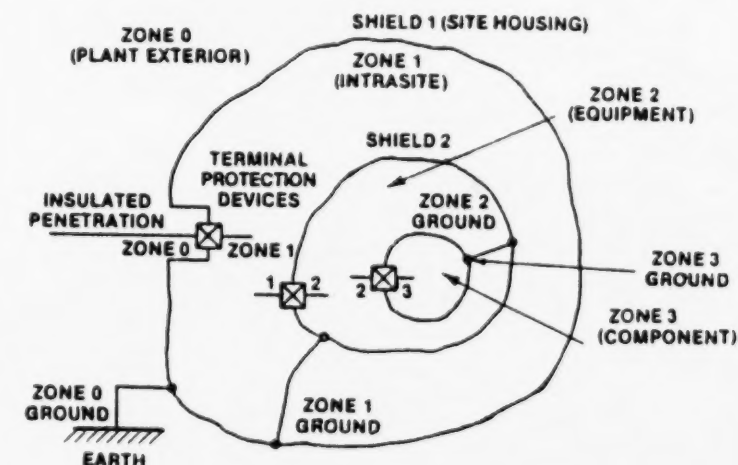
- a. Component (zone 2/3 boundary and zone 3)
- b. Equipment (zone 1/2 boundary and zone 2)
- c. Spaces (zone 1)
- d. Facility envelope (zone 0/1 boundary)
- e. Site (zone 0).

policy/sop

Component. A component is an assembly or a part thereof essential to the operation of some larger assembly (equipment). It is an immediate subdivision of the equipment to which it belongs. Classification of an item as a component depends on the frame of reference. For example, a radio receiver can be considered a component of a complete radio set (transmitter/receiver) if the radio set is part of a larger system. The same receiver could also be considered a piece of equipment, in which case the intermediate frequency (IF) amplifier section would be a component of the receiver. (188)

Equipment. Equipment includes any items, components, and parts, serving the communications function of generating, transmitting, conveying, acquiring, receiving, storing, processing, or using information in the broadcast sense. Any item required to support that function is also considered equipment. An item of equipment consists of one or more components in an enclosure (a cabinet or a rack). The enclosure is part of the equipment element. (188)

Spaces (intrasite). The volume within the prime housing of a communications facility is termed "spaces intrasite." It



policy/sop

includes that volume bounded by the plant prime housing enclosure and the exterior. This is the region that contains the cabling to and between equipment, cable racks and ducts, standard pallets and transportable shielded enclosures, alternating current (a.c.) and direct current (d.c.) power distribution, internal plumbing, air-conditioning, and interior building framework. (188)

Facility envelope (site housing). Prime or "site" housing shelters against weather. In a typical fixed facility, it consists of the building support structure, exterior walls, roof, and floor. Further, the facility envelope includes major structural or building subdivisions such as floors and ceilings for each story, interior wall material, and insulation. (188)

Site (plant exterior). The "site" is the region outside the facility envelope and is bounded by the envelope and the area in which the Government's ability to control design ends--generally at the facility boundary or fence lines. (188)

Each of these five zonal elements represents a physical region for which hardening is used. The amount of hardening in each physical region is balanced in a practical way to insure that the design practice can be realized and to provide a balanced margin of safety over the five elements. (188)

Design practice categories--Design practices that provide HEMP protection (hardening) to the zonal elements can be separated into three categories:

- a. Shielding
- b. Transient suppression
- c. Grounding.

Each category represents a distinct approach to preventing energy transfer from one zonal element to another. The categories provide the functions of energy reflection, absorption, and isolation necessary to the development of EM zone environments with increasing independence from the external environment. They are most effectively applied to the zone boundary, but can be used inside a zone. The following table shows protection techniques for each zone.

policy/sop

PROTECTION TECHNIQUES BY ENVIRONMENTAL ZONE (120) 3-9

<u>Zone 0 Exterior Environment</u>	<u>Zone 0/Zone 1 Boundary</u>
Decouple conductors and protect components	Use facility shield and penetration control
1. Buried cables 2. Plastic pipe 3. Cable shields 4. Antenna protection 5. Radio tower 6. Bonding 7. Facility power 8. Ground system	1. Metal liner 2. Reinforcement steel 3. Doors 4. Waveguide beyond cutoff 5. Air vents 6. Entry panel 7. EMP vault 8. Filters 9. Limiters 10. Grounds
<u>Zone 1 Interior Environment</u>	<u>Zone 1/Zone 2 Boundary</u>
Control equipment and grounding installations	Use equipment shield, penetration control, and circuit protection
1. Shielded cables 2. Conduit 3. Cable ducts 4. Exclusion zones 5. Lossy filters 6. Ground system	1. Shielded rooms 2. Closed cabinets 3. Cable trays 4. Cable bonding 5. Lossy filters 6. EMI filters 7. Limiters

issues and assumptions

1. Threat levels

The HEMP field interacts with site conductors, which act as antennas, to produce intense electrical transients on the conductors. The points of entry (POE) (next figure) that permit HEMP energy to penetrate the facility envelope and that ultimately can dissipate energy in components have been classed according to worst-case threat energy values in the following table. As the table indicates, because of their physical and electrical geometry, some penetrators pick up more energy than others. For example, compare the a.c. power line with the sewage line. Also, note that the last two items in this table, structures and apertures, relate to EMP diffusion penetration through a housing rather than to conducted electrical transient penetration. (188)

THREAT-LEVEL TRANSIENTS (188)

Point of entry	Worse-case energy value (decibel joules)
Alternating current power	70
Direct current power	60
Signal cable	50
Control cable	50
Antenna	50
Waveguide	50
Water	25
Sewage	25
Fuel	25
Air-conditioning	25
Grounding	50
Housing structure	0 (per m ²)
Housing apertures	0 (per m ²)

issues and assumptions

Detailed specifications have been developed for the POEs to each zonal element. The design practices in each section have been developed to reduce the transient levels to or below the specifications for the zonal element of higher number.

The specifications consist of a double exponential of the form:

$$S(t) = \frac{1}{r} \text{amplitude}(e^{10^5 t} - e^{-rt}),$$

where S = wave shape of specification signal with time

t = time (sec)

r = 0.43 x (rate of rise)/amplitude,

or they consist of a single damped sinusoid or a multiple damped sinusoid of the form:

$$S(t) = \text{amplitude}[e^{-at}(\sin 2\pi f_0 t)],$$

where a = given decay constant

f₀ = given frequency.

The next three tables give the parameters of these wave shapes (see also reference 188, tables 2 through 6).

All parameters for a POE must be met, and meeting them may require more than one wave shape and test for each POE. Specialized engineering skills, test methods, and equipment are required to develop and use the tables correctly. Help from a knowledgeable EMP engineer test contractor may be needed to insure such tests are done safely, correctly, and completely. (188)

The set of individual design practices and the alternatives presented for the prime housing volume constitute the minimum requirements to meet the allocated design practice effectiveness for the space (intrasite) zonal element. Specification requirements for the spaces are in a table below and are discussed in section 1.3.4 of reference 188. Transient levels must be reduced to or below the levels specified for the equipment and component functional elements.

The individual design practices and the alternatives presented for the facility envelope constitute the minimum requirements to meet the allocated design practice effectiveness for the site housing zonal element. Specifications for the facility envelope are in a table below and are discussed in section 1.3.4 of reference 188. Transient levels must be reduced to or below the levels specified for the space functional element. (188)

Issues and assumptions**2. EMP retrofitting versus new construction**

The level of funding available compared to the cost of the anticipated protective measures may dominate in determining if it is economical to abandon a site and rebuild with plans that include protective measures. (124) B-3

To minimize component burnout damage and digital system upsets in critical circuits, EMP protection should be considered in the design of all new or refurbished installations. The specific EMP protection techniques to be implemented must be chosen individually. (120) 2-1

3. Underground versus aboveground structures

Burying the structure provides additional reflection and penetration losses, depending on the earth's conductivity and dielectric constants. (17) 22

4. Shielding total building versus individual room

When feasible, the overall building should be shielded in preference to rooms or areas. Individual room or area shields should only be used to provide additional protection for critical equipment when normal protective methods will not reduce EMP to an acceptable level, or when, in retrofitting an existing structure, the cost of protecting the entire building is excessive. (15b) 1-18

Issues and assumptions**PRIMARY PENETRANTS**

GROUNDING
AC POWER
DC POWER
SIGNAL AND
CONTROL CABLES
ANTENNA
WAVEGUIDE

SECONDARY PENETRANTS

WATER
SEWAGE
FUEL
AIR-CONDITIONING

DIFFUSION SOURCES

HOUSING STRUCTURE
HOUSING APERTURES

EQUIPMENT

POINTS OF ENTRY TO COMMUNICATIONS FACILITY

requirements	criteria	commentary
1. Protection of communication components and wiring from the destructive energy contained in airborne magnetic and electric fields through shielding	1. Shielding--The objective of shielding is to make the EM environment in one region relatively independent of the environment in an adjacent region (on the other side of the shield). Shielding techniques change or reduce the unwanted electric and magnetic field energy and waveform characteristics by reflection and absorption at metallic boundaries that enclose and separate equipment, components, and cables. Typical applications are to shield buildings, rooms, equipment, cables, and components. (16) 15 Shielding can also be achieved through isolation or configuration. Isolation techniques prevent the transfer of an unwanted transient signal by breaking or opening such a signal's path and by reducing mutual coupling between conductors through separation and other techniques. Examples of such techniques are dielectric separators in waveguides; fiber optics in signal lines; and separation, routing, and reconfiguration of conductors to isolate and prevent mutual coupling between cables. (188) (For additional information on a grounded lightning protection subsystem see SB4, Grounding/Bonding/Shielding.) a. Spaces--Shielding shall be implemented in the intrasite functional element through the use of cable shields, RFI connectors, or cable trays. One or more distribution frames shall be used. (16) 64 (See also SB4--"Grounding, Bonding, and Shielding") b. Facility envelope--Shielding used in the facility envelope provides the interior with some level of protection from electromagnetic fields when they result from illumination of the building's exterior surface by HEMP. The extent to which the fields are attenuated is directly related to the skeletal structure. (16) 72 c. Site--Site shielding is concerned with proper design and installation of power, signal, and utility lines before they enter the facility.	1. An all-welded steel sheet room is the only way to provide 120 decibels of shielding over the EMP range up to 10 gigahertz. Other types of treatments will provide some lower level of shielding that will be quite frequency dependent. For some applications, the shielding from the other methods may be good enough. b. Doors should be commercial shielded doors for any shielding requirement over 50 to 60 decibels. Waveguide below cut-off criteria can be found in <u>Ground Based Systems EMP Design Handbook</u>, pages 24-32. Windows are not recommended for high-performance EMP structures (100 to 120 decibels).
2. Protection from unwanted transient signal characteristics without affecting the desired signals through suppression of the transient signals or through rejection.	2. Transient suppression--Transient suppression techniques reduce or alter the unwanted transient signal characteristics of magnitude, rise time, frequency content, and energy between signal line or power line wires or wire pairs. This is done without affecting the desired signal or power transmission. Such techniques typically consist of inserting frequency selective shunt and series impedances or nonlinear devices such as voltage limiters into the transient signal path to divert and absorb the unwanted	

requirements	criteria	commentary
3. Protection from energy developed in the <u>Grounding System</u>.	transient energy. Typical suppression devices are inductors, capacitors, resistors, filters, and Zener diodes. (188) Spaces. Transient suppression design practices shall be applied to conductors entering the distribution frame from the site housing interface to the local distribution frame. (16) 67 Facility envelope. Design practices for CMR are not a requirement of the facility envelope, but their addition improves protection. (16) 81 Site. Standard lightning protection is the minimum suppression requirement. 3. Grounding--Grounding techniques alter or reduce the common-mode energies, voltages and currents of unwanted transients that appear in the ground system without affecting the requirements for signal, power, and personnel safety that result from lightning, electrostatic potentials or power fault conditions. Examples of these techniques include: (16) 15 • Those that limit the maximum allowable loop area geometry for frame grounds in open equipment racks or the maximum length of ground line length to insure EMP surge operation • Those that define the grounding techniques for cable shields and shield enclosures that will divert the common mode to absorption or reflection devices for isolation and transient suppression. Spaces. All grounding requirements of MIL-STD-188-124 shall be followed, with major exceptions and additions shown in Guidance. (16) 70 Facility envelope. All grounding requirements of MIL-STD-188-124 shall be followed plus the additional information shown in Guidance. (16) 81 Site. All external grounding requirements of MIL-STD-188-124 shall be followed. Also, for coaxial antenna leads, the cable shield should be grounded to the mast supporting the antenna and to the entry panel at the facility envelope. (16) 85 See also SB4--Grounding/Bonding/Shielding.	

requirements	criteria	commentary
4. EMP hardness testing is necessary to verify that a facility actually has its designed EMP hardness.	4. Hardness testing--Structural shielding and isolation and suppression devices must be tested because failure modes for EMP protection often are not physically obvious. Acceptance testing should be specified on completion of construction. The types of tests fall roughly into the following categories: - Threat-level radiated pulse - Sealed radiated pulse - Radiated CW (continuous wave) - Conducted (injected) pulse - Conducted CW. Pulse testing has not been standardized. Radiated CW tests, however, are usually based on MIL-STD-285, NSA 65-5, IEEE 299.	

guidance EMP/HEMP 1. Shielding

1. To protect electrical wiring and components from magnetic and electric fields, some type of shield must be used. The shield must surround items to be protected. This type of protection does not completely isolate the item from the EM field but attenuates the field strength to an acceptable level. (24) B-1

EMP shielding requirements are ultimately determined by equipment and component level susceptibility, that is, operational upset and damage thresholds. The item's mission determines the degree of protection necessary. For example, a nondamaging pulse entering communications equipment will probably have very little effect on system operation, whereas the same pulse in a digital system may upset its operation. Structural shielding protects equipment installed inside the shield by reducing ambient field levels and then limiting the magnitude of interfacing signal that can be picked up by that equipment. Suitable isolation techniques must be used in conjunction with the structural shield to insure the protection requirements are maintained. Shielding requirements usually are designated by specifying attenuation over a frequency range.

Equipment susceptibility is variable and depends on the configuration of the individual equipment. In general, it may not be practical to determine each item's susceptibility. However, it can be argued that an attenuation of 120 decibels from the outside world to the component level (zone 0 to zone 3) is good enough to protect that component from EMP effects. Since attenuation from any of the zone boundaries (except a known quality shielded room) is probably unknown and also a function of frequency, the safest approach may be to specify any shielding requirements necessary in that shielded room. A 100- to 120-decibel room probably will need to be completely constructed with welded sheet metal, and must have high-performance doors.

a. Spaces**1. Design objective**

Power, signal, control, and antenna cables are shielded from the vault distribution frame to the equipment by cable shields or properly designed trays, conduits, or ducts. (188)

2. Alternating current power

The a.c. power distribution in the entry vault area shall be isolated from the signal and control distribution areas by using (1) separate, metallically enclosed compartments on the distribution frame or (2) separate distribution frames. For all shielding, the bonding requirements of MIL-STD-188-124 shall be followed.

guidance EMP/HEMP 1. Shielding

The a.c. power cables shall be either (1) shielded or (2) routed through metallic conduit or trays that provide a 360-degree metallic enclosure. Sections of conduit or trays shall be bonded peripherally to each other and to the metallic ground plane. The conduit or trays should form part of the metallic ground plane. All conduits, trays, and ducts containing a.c. power shall be connected electrically to the distribution frame. The distribution frame shall be grounded in the vault area.

The a.c. power shall be isolated from all other power and signal conductors by separate routing, conduit, channels, or conductive septa in ductwork and cable trays. The a.c. power cables shall be isolated from the d.c. power, signal, and control cables of the distribution frame. (188)

3. Direct current power

The d.c. power distribution area shall be isolated from the signal and control distribution areas when electrically possible by using (1) separate, metallically enclosed compartments on the frame or (2) separate distribution frames. For all shielding, the bonding requirements of MIL-STD-188-124 shall be followed.

The d.c. power cables shall be either (1) shielded or (2) routed through metallic conduit or trays that provide a 360-degree metallic enclosure. Sections of conduit or trays shall be bonded peripherally to each other and to the metallic ground plane. The conduit or trays should form part of the metallic ground plane.

The d.c. power shall be isolated from all a.c. power, signal, and control conductors by using separate routing, conduit, channels, or conductive septa in ductwork and cable trays. The d.c. power cables shall be isolated from the a.c. power, signal, and control cables of the distribution frame and from water, sewage, fuel, and air-conditioning lines. The d.c. power shall be isolated from these other conductors by a minimum separation of 30 centimeters in the intrasite area. (188) The d.c. power return shall be isolated from the distribution frame. (188)

4. Signal and control cables

Shielding shall be implemented by using (1) cable shields and RFI-type connectors or (2) cable trays or ducts for routing signal and control cables from the distribution frame in the vault area to the equipment. Shielded cables from the site housing interface to the distribution frame are a design objective.

Signal and control cables should be isolated from other sources of HEMP energy (for example, a.c. power cables and

guidance EMP/HEMP 1. Shielding

water lines) by separation or by using conductive septa in cable trays or separate duct or conduit systems. Classes of signal and control cables should be isolated from each other. Shielded cable use is a design objective. For example, totally internal signal and control cables should be isolated by routing or by metallic ducts, conduit, or trays from cables that penetrate the facility envelope from the site. Short cable runs should be isolated from longer ones when possible. Signal, control, and antenna cables must be isolated from water, sewage, or air-conditioning lines. These cables shall be isolated by a minimum of 30 centimeters from any power, water, sewage, or air-conditioning conductor along the cable extent.

Signal and control cables entering the facility must be treated at the entry vault distribution frame. The signal and control distribution area shall be isolated from a.c. or d.c. power areas by using (1) separate, metallically enclosed compartments on distribution frames or (2) separate frames. RFI-type connector use on the equipment side of the distribution frame is a design objective. (188)

5. Antenna

Antenna cables must be routed through the vault distribution frame in the entry vault and shielded in the same way as the signal and control cables. Antenna cables can be routed directly to equipment or components when doing otherwise would degrade equipment performance. (188)

6. Waveguide

The waveguide shall be isolated from all other conductors, whether signal-carrying or non-signal-carrying. The waveguide shall be isolated from other conductors by a minimum of 30 centimeters along the length of the guide. At the distribution frame, a separate waveguide entry flange shall be provided. (188)

7. Water, sewage, fuel, and air-conditioning lines and facility's metallic structure

Water, sewage, fuel, and air-conditioning conductive lines as well as the facility's metallic structure should provide an isolated area for the single-point ground plane and equipment installation. This isolated area should be obtained by physical separation from these conductive lines and from all metallic structures of the facility. Separation should be 30 centimeters or more from any internal conductor and 0.9 meters or more from the facility envelope walls and associated conductive service entries and routings. (188)

8. Housing structure and apertures**guidance EMP/HEMP 1. Shielding**

Equipment in the spaces' functional element are isolated by the separate routing of cable conductor classes and the installation away from wall and apertures. All cables and power conductors should be routed away from facility envelope apertures such as windows and doors by a distance of at least twice the largest aperture dimension. Equipment should be placed no closer than twice the longest aperture dimension from those apertures (for example, doors, windows, vents). Equipment should be located no closer than 1 meter from external walls (zone 0/1 boundaries). (188)

b. Facility envelope**1. Envelope structure**

All enclosures external to the facility envelope containing electronic equipment or components are considered the facility envelope and shall be constructed using the following practices.

Structures shall be grounded by the requirements of MIL-STD-188-124. (188) 121 Shielding used in the facility envelope provides the interior with some level of protection from EM fields when they result from HEMP illumination of the building's other surface. The amount of field attenuation is directly related to the skeletal structure's construction makeup.

The facility envelope shall be constructed according to one of the following practices. These practices shall afford as a minimum the measure of shielding required for the shielding effectiveness allocation. Shielding against HEMP is maximized by using solid metal as the shield material. Shielding also can be provided by reinforcement steel and wire mesh.

a. Poured-in-place steel-reinforced concrete housing-- Construction material for supporting poured-in-place concrete foundations, floors, and walls can give adequate shielding provided the reinforcement bars (rebars) are welded at joints and intersections to form many continuous conducting loops or paths around the surface to be shielded. The requirements for such construction are as follows.

- At a minimum, single-course rebars are placed 14 inches (36 centimeters) or less on-center. Cross-member rebars are placed 3 feet (0.9 meters) or more on-center.
- The quality of welds at all corners and intersections of rebars shall be in accordance with MIL-STD-188-124.

guidance EMP/HEMP 1. Shielding

- The wall rebar shall be welded to that of the floor and the roof.
- In housing that has a roof other than concrete with rebars, a conducting roof shall be provided by sheet metal or wire mesh. This material must be bonded to the rebars of the walls at a minimum of 12 inches (30 centimeters) along the intersecting periphery.

b. Welded wire mesh construction--Welded wire mesh in walls, floors, and the roof of the facility envelope has been shown to provide effective shielding in new facilities and in retrofitting. The mesh shall be totally interconnected by welding to essentially form a cage around the envelope interior. The mesh can provide the partial reinforcement needed for concrete construction. The individual wires shall be joined to form an electrical loop around the perimeter of the area to be shielded. At each seam where the mesh meets, each wire must be welded or brazed to a corresponding wire, or the meshes can be connected by a continuous strip. Apertures require the design practices given in section 5.2.2 of reference 188. Requirements for the welded mesh are as follows.

- The mesh should have a grid of 6 x 6 inches (15 x 15 centimeters) or less of AWG 6 wire.
- The mesh strips should be welded to each other per MIL-STD-188-124.

c. Metal sheet construction--Exterior shielding that uses metal sheets should have continuously welded seams, spot-welded seams with 2-inch (5-centimeter) overlap spaced at no greater than 8-inch (20-centimeters) centers, or bolted seams with 2-inch (5-centimeter) overlap at no greater than 8-inch (20-centimeter) centers on all outside surfaces of the structure, including those of the base slab, roof, and exterior walls. Bolted seams require special metallization treatment to insure the joints' conductivity after weathering. This technique can be used for both new and retrofit facilities. (188)

2. Envelope apertures

Apertures are designed openings, such as doorways, ventilators, exhaust holes, and intake holes in a shielded system. Defects in seams and welded joints at these openings reduce the facility envelope's shielding integrity. Loss of shielding effectiveness can be minimized as follows.

a. Doors--Since doors must be free to open, they constitute weak links in the room's shielding

guidance EMP/HEMP 1. Shielding

continuity. All doors leading to the site exterior or to other unshielded areas must be metal, including the frame. The frame should be bonded to the rebar, the wire mesh, or the metal sheet at a maximum interval of 12 inches (30 centimeters) along its periphery.

b. Entryways--Stairwells, halls, vestibules, and foyers interfacing the envelope entry areas and the equipment or bays are a desirable construction feature. Entryway length should be at least 1.1 times the largest dimension of their apertures for effective waveguide-below-cutoff properties. To be effective, all conductors such as railings and heating ducts should be replaced by nonconductive elements. All power lines should be in conduit bonded to the entryway structure (rebar, metal panels) at 12-inch (30-centimeter) intervals.

c. Windows--Windows greater than 3 square feet (0.4 square meters) shall be covered with metallic screen of fine-knitted wire laminated between two layers of acrylic or glass. Metal wire with typical diameters of 2 mils (51 microns) (8 to 10 holes/centimeter) or 4.5 mils (114 microns) (4 to 5 holes/centimeter) are acceptable. An inexpensive alternative is to use standard window screening bonded conductively to the metal frame per MIL-STD-188-124. Window frames shall be metallic and shall be bonded to the facility envelope rebar, wire mesh, or sheet metal at a maximum interval of 12 inches (30 centimeters) along its periphery.

d. Air or vent apertures--Air or vent apertures 12 inches (30 centimeters) or more on a side should have screening, steel honeycomb, or metallic louvers bonded around their edges to the rebar, the wire mesh, or the sheet metal of the housing structure.

e. Cable routing and equipment placement--Cables shall not be routed and equipment shall not be placed within two times the greatest aperture dimension from that aperture.

f. Cable entry plate--A cable entry plate shall be provided with the following specifications. (188) 103

- The plate should be 1/4-inch (6-millimeter) steel or equivalent.
- The plate should be bonded, preferably welded, to the rebar, the wire mesh, or the sheet metal of the housing structure.
- The size shall be large enough to meet the isolation distance requirements of section 5.3 in reference 188.

guidance EMP/HEMP 1. Shielding

- The plate shall be installed in the cable entry vault discussed below.

3. Conductor penetrations

All penetrations should enter the facility envelope at a common location, generally a cable entry vault. This prevents currents from being picked up on one cable passing through the envelope and continuing out another cable on the opposite side. It also prevents large potential differences between cables in the spaces. Power, signal, control, and antenna cables should be isolated from each other within the vault. Transient suppression devices should be used inside the vault or at its interfaces.

4. Retrofit building shields

Methods b and c above can be used in retrofitting existing structures. Mechanical and architectural considerations, such as the structure's load bearing capability, will determine how the shield can be constructed. It is often impossible to provide the sixth side (the floor) to complete the shield. Where this is the case, an acceptable option is to provide a shield extension or skirt that extends into the earth ground. The sixth side is, thus, provided by the earth ground.

The building skirt must be buried at least 6.2 feet (2 meters) deep and must make electrical contact with the earth along this burial depth. The skirt can be solid sheet or wire mesh.

Standard measures should be taken to prevent corrosion and insure an adequate shield life. This shield skirt approach is not recommended in areas for which the earth's conductivity is poor (that is, less than 10^{-3} mhos/m) or for which it was difficult to achieve a 10-ohm earth electrode subsystem. (188)

5. Electrical service entrances

All electrical service entrances should be installed in rigid steel conduits with tight threaded couplings, and the entrance conduit should be grounded as it enters the site housing. Electrical service entrances shall include an entrance plate. The service panel shall be located as close to the entrance plate as practical. (188)

6. Signal and control cables

Signal and control cables shall enter the site housing through a cable entry panel (see the next two figures).

- a. Shielded and coaxial cables shall have their

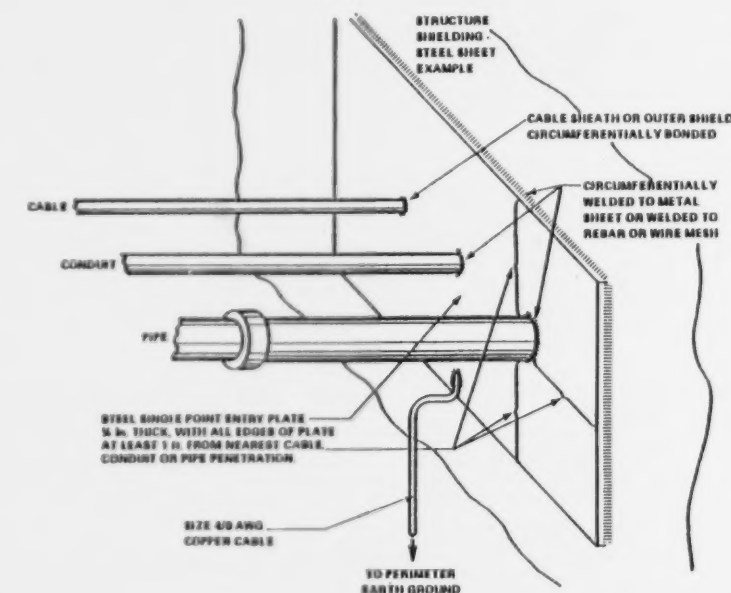
guidance EMP/HEMP 1. Shielding

shields bonded circumferentially to the outside wall of the entry panel for the cable entry vault.

- b. External cables are most effective against HEMP when they are shielded. Unshielded external cables shall have transient suppression devices installed.

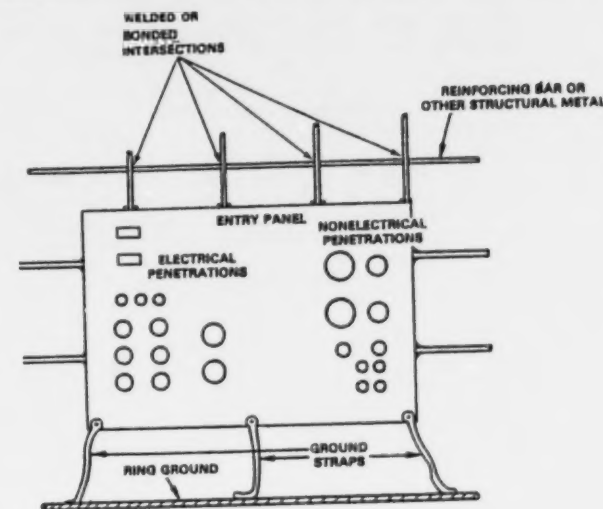
c. Unshielded external cables entering the vault shall be separated from the inner conductors of shielded cables inside the entry vault. The conductors must be separated by 12 inches (30 centimeters) or more along their complete route through the vault. If this separation is not possible, a metallic septum, conduit, or tray shall be used to isolate the unshielded cables.

d. Signal and control cables shall be collocated on the entry panel and each cable entry shall be separated by 6 inches (15 centimeters) or more. The signal and control group entry shall be isolated 12 inches (30 centimeters) or more from the other classes of conductor entry on the panel. (188)



ENTRY PLATE SHOWING RIGID CABLE, CONDUIT, AND PIPE PENETRATIONS. (188) 110

guidance EMP/HEMP 1. Shielding



GROUND CONNECTIONS FOR SITE HOUSING ENTRY PANEL FOR REINFORCEMENT BAR SITUATIONS. (188) 111

All cable shields, conduit, armor, and other non-signal-carrying conductors shall be bonded to the entry panel with 360-degree circumferential connections. Such connections should be made by welding, brazing, or soldering the conductors to the entry panel or by using durable mechanical connectors. (188)

7. Waveguide

All waveguide should enter the envelope through the entry plate, if such entry is practical. If operational requirements prohibit connection to the plate, a separate plate or more than one plate must be provided. The waveguide should be bonded peripherally to the plate, and the plate should be grounded to the perimeter earth ground.

Waveguide can be grounded by brazing or bolting the feed-through waveguide to the entry panel. The optimal waveguide connection bonds the complete perimeter of the waveguide to the entry panel's outside surface. (188)

8. Water, sewage, fuel, and air-conditioning lines

Nonelectrical penetrations such as pipes for water, fuel,

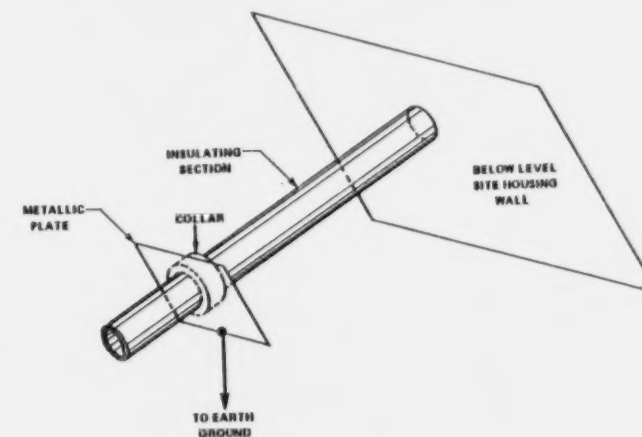
guidance EMP/HEMP 1. Shielding

hydraulic and pneumatic systems, and exhaust ducts should enter the envelope through one or more entry plates (see the two preceding figures) or through separate apertures as necessary. The entry plates or their parts should be isolated into two or more sections--one for electrical penetrations and the other for nonelectrical penetrations. The ground lead shall be connected to the earth electrode system near the entry plate.

Water and sewage lines--For metal pipe construction, a nonconducting line approximately 10 feet (3 meters) or longer should be connected to the metal pipe and used as the site housing penetrator. The end of the metallic pipe away from the building should be grounded to the earth ground ring as the following figure shows. The next figure shows another practice for treating metal pipe penetrations. Nonmetallic pipes such as polyvinyl chloride (PVC) penetrating the envelope below grade level need no EMP isolation.

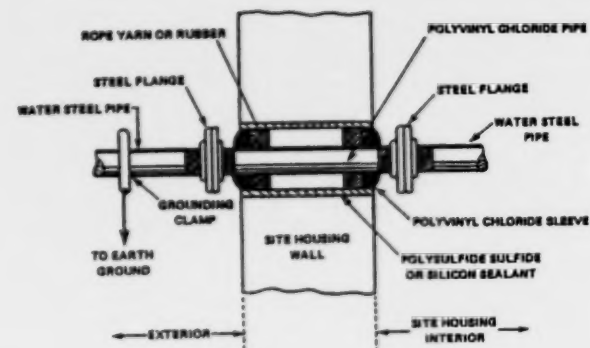
Fuel lines--Fuel lines entering the envelope should be below grade level and bonded circumferentially to the entry plate.

Air-conditioning lines--Power and refrigerant copper tubing from the air-conditioning heat exchanger shall be welded or soldered to the envelope entry plate. (188)



INSULATING SECTION INSERT FOR METALLIC PIPE ISOLATION FROM FACILITY ENVELOPE. (188)

guidance EMP/HEMP 1. Shielding



PENETRATION TREATMENT OF WATER PIPE THROUGH BUILDING FOUNDATIONS (188)

9. Typical Penetration Details

It is relatively easy to achieve the required shielding effectiveness in a welded box without openings and penetrations. However, to preserve this performance in a real facility with numerous penetrations requires careful attention to each of these potential leakage points. The table below is a typical example of penetration details that must be written into contract documents for a communication facility.

guidance EMP/HEMP 1. Shielding

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SHIELD PENETRATION SCHEDULE

Room No.	Penetration		Type of Penetration	Location			Det./Sht.	Remarks
	No.	Size		Wall	Ceiling	Floor		
100	1	2" Ø	DRINKING FOUNTAIN WASTE PIPE				P/M-6	WELD PIPE TO LINER
101	2	4" Ø	WASTE LINE CLEANOUT				J/M-6	WELD PIPE TO LINER
101	2	3" Ø	FLOOR DRAIN				J/M-6	WELD PIPE TO LINER
101	1	2" Ø	PLUMBING VENT				Q/M-6	WELD PIPE TO LINER
101	1	1-1/2" Ø	FIRE SPRINKLER TEST CONNECTION				M-6	WELD PIPE TO LINER
102	1	4" Ø	PLUMBING VENT				Q/M-6	WELD PIPE TO LINER
102	4	1" Ø	HEAT EXCHANGER COOLANT LINES				A/M-1	WELD PIPE TO LINER
102	2	3" Ø	FLOOR DRAIN				J/M-6	WELD PIPE TO LINER
103	3	3" Ø	FLOOR DRAIN				J/M-6	WELD PIPE TO LINER
103	1	24 x 24"	EXHAUST FAN WAVE GUIDE				S/M-7	4" x 4" HONEYCOMB MATRIX
103	1	40 x 40"	AIR INTAKE WAVE GUIDE				E, F, G, A-10	4" x 4" HONEYCOMB MATRIX
103	1	16" Ø	BOILER FLUE				V/M-7	PIPE SLEEVE WELD TO LINER
104/106	1	4" Ø	SOIL PIPE				P/M-6	WELD PIPE TO LINER
104/106	1	4" Ø	PLUMBING VENT				Q/M-6	WELD PIPE TO LINER
104	1	2" Ø	FLOOR DRAIN				J/M-6	WELD PIPE TO LINER
106	1	2" Ø	FLOOR DRAIN				J/M-6	WELD PIPE TO LINER
106	1	8" x 10"	EXHAUST FAN WAVE GUIDE				S/M-7	4" x 4" HONEYCOMB MATRIX
107	1	24 x 24"	REFRIGERANT LINES/PLATE				D, E/M-2	26" x 26" PLATE WELD TO LINER
108	2	3/4" Ø	DIESEL OIL GAGE				P/M-6	WELD PIPE TO LINER
108	4	3/4" Ø	DIESEL OIL LINES				P/M-6	WELD PIPE TO PLATE
108	3	5'-4" w x 8'-8" h	GENERATOR VENT EXHAUST				H/M-5	4" x 4" HONEYCOMB MATRIX
108	3	16'-8" w x 8'-8" h	GENERATOR VENT AIR INTAKE				E, F, G, A-10	4" x 4" HONEYCOMB MATRIX
108	1	32" x 32"	SSUPE EQUIPMENT EXHAUST				S/M-7	4" x 4" HONEYCOMB MATRIX
108	1							26" x 26" PLATE WELD TO LINER
108	1	3" Ø	FLOOR DRAIN				J/M-6	WELD PIPE TO LINER
109	1	3" Ø	FLOOR DRAIN				J/M-6	WELD PIPE TO LINER
109	1	2" Ø	DOMESTIC WATER				K/M-6	WELD PIPE TO LINER
109	1	2" Ø	SPRINKLER MAIN				K/M-6	WELD PIPE TO LINER
109	1	2" Ø	GAS PIPE				K/M-6	WELD PIPE TO LINER
109	1	12" x 16"	EXHAUST FAN WAVE GUIDE				W/M-7	4" x 4" HONEYCOMB MATRIX
109	2	1" Ø	HEATING WATER				K/M-6	WELD PIPE TO LINER
110	1	2" Ø	FLOOR DRAIN				J/M-6	WELD PIPE TO LINER
101	1	3' x 7'	DOOR 101B				A-13	
108	1	6' x 7'	DOOR 108B				A-13	
110	1	1/2" Ø	ELECTRICAL POWER CONDUIT				C/E-8	POWER FILTER SHALL BE 1-2W, 120V, FILTRON FSR-X-1582 OR APPROVED EQUAL
101	4	4" Ø	CONDUITS FOR FUTURE COMM. CABLES				DETAIL I/C-5	CAP ALL ENDS
102	2	10" Ø	ANTENNA CABLE CONDUITS				A/C-5	FOR ATTACHMENT OF 40 CABLE
102	1	3/8" Ø	3/8" STEEL STUD				B/E-6	POWER FILTERS SHALL BE SUITABLE FOR
103	2	1" Ø	CONDENSING UNITS POWER CONDUIT				B/E-8	POWER FILTERS SHALL BE SUITABLE FOR
103	1	1-1/4" Ø	CONDENSING UNITS CONTROL CONDUIT				B/E-8	CONTROL FILTERS SHALL BE SUITABLE FOR CONDENSING UNITS PROVIDED, SEE SPEC. SECT. 13C
111/109	4	4" Ø	ELECTRICAL POWER CONDUITS				B/E-8	
111	1	1/2" Ø	FIRE ALARM				B/E-8	
112	1	1/2" Ø	FIRE ALARM				B/E-8	
112	1	6" Ø	300 PAIR TELEPHONE FILTER				B/E-9	

guidance EMP/HEMP 1. Shielding**C. Site (Alternating and direct current power and antenna, signal, and control cables)****1. Shielding**

All a.c. power, d.c. power, signal, and control cables that enter the facility envelope and that are more than 300 feet (90 meters) long shall be buried. Burial depth should be 3 feet (1 meter) or more under the earth's surface for a length of 100 feet (30 meters) or more immediately before entry to the envelope. This requirement can be met by direct burial or by cable trenches and buried conduit.

Alternating current power conductors shall be isolated from signal and control cables by separate routing at and beyond 10 feet (3 meters) from the facility envelope. When mobile electric power is available, the power cables should be routed on or below the earth's surface and should have their leads isolated from signal and control cables at and beyond 10 feet (3 meters) from the envelope. Isolation is achieved by a cable separation of 3 feet (1 meter) or more. In trenches, this isolation can be achieved through electrically conductive septa or conduit bonded to the reinforcement steel at intervals no greater than 3 feet (1 meter) along its length. MIL-STD-188-124 bonding requirements apply.

Cables originating from different locations shall have physical isolation through routing. Cables originating from the same location shall be routed together. Cables shall not run adjacent to ground lines or other long conductors such as pipes and waveguides. (188)

2. Cable trenches

Cable trenches must be constructed of reinforced concrete. Rebars should be bonded together conductively at 10 foot (3-meter) intervals and grounded to the facility envelope rebar and earth electrode subsystem. An electrically continuous reinforcing material such as rebar is required for the entire length of the trenches. (188)

3. Conduit

Metal conduit used for buried cables shall be electrically continuous. It shall be bonded to the facility envelope and to the earth electrode subsystem. (188)

4. Waveguide

Waveguide should be routed directly to the envelope entry panel and should be isolated from other long conductors when possible. (188)

guidance EMP/HEMP 1. Shielding**5. Water, sewage, fuel, and air-conditioning lines**

Metallic lines or pipes associated with water, sewage, fuel, and air-conditioning shall be below grade if they extend more than 10 feet (3 meters) from the facility envelope.

When local codes permit, water and sewage lines should be isolated by nonconducting lines. Waveguide bridges shall be constructed of metal. The components comprising the bridges shall be bonded together to effect a conductive enclosure. The bridges shall be bonded conductively to the waveguide tower and to the facility envelope wall structure (rebar or metal sheet).

External metallic structural equipment such as fences, ladders, fire escapes, gutters, railings, and other supporting conductors and their attachments to the envelope should be isolated from cable and waveguide entry panels. No connection to these external metallic conductors is permitted to enter the facility envelope. This equipment must be grounded according to MIL-STD-188-124. (188) ---

guidance EMP/Hemp 2. Suppression-Rejection**2. a. Spaces****1. Alternating current power**

Proper attention to the following directions effectively protects against HEMP transients on incoming a.c. power lines.

a. Secondary a.c. surge arrester--A properly selected secondary a.c. surge spark gap arrester must be installed on the distribution frame at the entry vault for each neutral and hot conductor. The surge arrester installed must have the following specifications to insure suitable protection.

- Minimum d.c. voltage rating of 2 times a.c. root mean square (rms).
- Maximum d.c. voltage rating of 5 times a.c. rms.
- Minimum energy requirement of 3 kilojoules.
- Minimum rate of rise of 1 kilovolt per nanosecond.
- Maximum firing voltage (impulse sparkover voltage) of 5 times d.c. voltage rating at minimum rate of rise.
- Minimum peak surge current of 1 kiloamp.
- Maximum discharge voltage at peak surge current of 100 volts.

The surge arrester must quench automatically under normal power levels.

b. Installation of secondary a.c. surge arrester--Proper installation of the surge arrester is of vital importance for optimal operation. All surge arresters should be installed according to the manufacturer's recommendations and the following installation criteria.

- Keep interconnecting lead lengths as short as possible--6 inches (15 centimeters) or less from the line to the ground point.
- Use interconnecting wire which is large enough to preclude adding resistance and inductance in the transient path to ground through the surge arrester. Use at minimum an AWG 4 insulated and stranded copper wire.

guidance EMP/Hemp 2. Suppression-Rejection

- Route interconnecting wire as straight and direct as possible with no sharp bends and with the least number of bends possible.

c. Other devices--All other active or passive devices installed on the a.c. power line must be 5 feet (1.5 meters) or more beyond the point of surge arrester installation. The surge arrester shall be close to the a.c. power POE. (188)

2. Direct current power

The transient suppression requirements for a.c. power apply to both the d.c. line and its return with the following changes to the surge arrester specifications. (188)

- Minimum d.c. voltage rating of 2 times a.c. voltage rating or 300 volts, whichever is higher.
- Maximum d.c. voltage rating of 5 times a.c. voltage rating or 1.5 kilovolts, whichever is lower.

3. Signal and control cables

From each individual signal/control cable conductor, a transient suppressor shall be applied to ground. This device must be the spark gap type and must meet the following specifications.

- Minimum d.c. voltage rating of 2 times normal operating voltage or 300 volts, whichever is higher.
- Maximum d.c. voltage rating of 5 times normal operating voltage or 1.5 kilovolts, whichever is lower.
- Minimum energy requirement of 10 joules for shielded cable and 1 kilojoule for unshielded cable.
- Minimum rate of rise of 1 kilovolt per nanosecond.
- Maximum firing voltage (impulse sparkover voltage) of 5 times d.c. rating at minimum rate of rise.
- Minimum peak surge current of 5 amps for shielded cable and 500 amps for unshielded cable.
- Maximum discharge voltage at peak surge current of 100 volts.

The device must quench automatically under normal signal levels. All other active or passive devices used on the signal or control cables must be at least 5 feet (1.5 meters) beyond the point at which transient suppressors are installed. (188)

guidance EMP/Hemp 2. Suppression-Rejection**4. Antenna**

Transient suppressors must be applied to antenna leads operating below 300 megahertz (very high frequency--VHF). A spark gap transient suppressor must be applied to each antenna lead conductor (excluding shields) carrying signals below the ultra high frequency (UHF) range. The spark gap must meet the following specifications.

- Minimum d.c. voltage rating of 4 times operating voltage or 2 kilovolts, whichever is higher.
- Maximum d.c. voltage rating of 8 times normal operating voltage or 5 kilovolts, whichever is lower.
- Minimum energy requirement of 100 kilojoules
- Minimum rate of rise of 5 kilovolts per nanosecond.
- Maximum firing voltage (impulse sparkover voltage) of 5 times d.c. voltage rating at minimum rate of rise.
- Minimum peak surge current of 2 kiloamps.
- Maximum discharge voltage at peak surge current of 1 kilovolt.
- Maximum insertion loss of less than acceptable minimum system loss.

The device must quench automatically under normal signal levels. For systems higher in frequency, special designs, custom devices, or both must be used to fulfill the requirements of low insertion loss and low-impedance shunting of the unwanted transient to ground. (188)

b. Facility envelope**1. Alternating current power**

Proper attention to the following requirements effectively protects against HEMP transients on incoming a.c. power lines.

a. Secondary a.c. surge arrester--A properly selected secondary a.c. surge spark gap arrester shall be installed at the facility main service disconnection point in the entry vault. This surge arrester shall have the following specifications to insure suitable protection.

- Minimum d.c. voltage rating of 2 times a.c. rms voltage.
- Maximum d.c. voltage rating of 5 times a.c. rms voltage.

guidance EMP/Hemp 2. Suppression-Rejection

- Minimum rate of rise of 1 kilovolt per nanosecond.
- Maximum firing voltage (impulse sparkover voltage) of 5 times d.c. voltage at minimum rate of rise.
- Minimum peak surge current of 1 kiloamp.
- Maximum discharge voltage at peak surge current of 100 volts.

The surge arrester must quench automatically under the normal power levels.

b. Installation of surge arresters--Proper installation of the surge arrester is of vital importance for optimal operation. All surge arresters shall be installed according to the manufacturer's recommendations and the following installation criteria.

- Keep interconnecting lead lengths as short as possible--6 inches (15 centimeters) or less from the line to the ground point.
- Use interconnecting wire which is large enough to preclude adding resistance and inductance in the transient path to ground through the surge arrester. Use at minimum an AWG 4 insulated and stranded copper wire.
- Route interconnecting wire as straight and direct as possible with no sharp bends and the least number of bends possible.

c. Loads--All active or passive loads installed on the a.c. power line should be 5 feet (1.5 meters) or more beyond the point of surge arrester installation. The arrester shall be close to the a.c. power POE. (188)

2. Direct current power

Direct current power is usually contained inside the facility envelope. If d.c. cables are required to penetrate the envelope, the transient suppression practices for a.c. power apply to both the d.c. line and its return, with the following changes to the surge arrester specifications. (188)

- Minimum d.c. voltage rating of 2 times a.c. voltage rating or 300 volts, whichever is higher.
- Maximum d.c. voltage rating of 5 times a.c. voltage rating or 1.5 kilovolts, whichever is lower.

guidance EMP/Hemp 2. Suppression-Rejection**3. Signal and control cables**

From each individual signal/control cable conductor, a transient suppressor of the spark gap type shall be applied to ground. The transient suppressor shall meet the following specifications.

- Minimum d.c. voltage rating of 2 times normal operating voltage or 300 volts, whichever is higher.
- Maximum d.c. voltage rating of 5 times normal operating voltage or 1.5 kilovolts, whichever is lower.
- Maximum energy requirement of 10 joules for shielded cable and 1 kilojoule for unshielded cable.
- Minimum rate of rise of 1 kilovolt per nanosecond.
- Maximum firing voltage (impulse sparkover voltage) of 5 times d.c. voltage rating at minimum rate of rise.
- Minimum peak surge current of 5 amps for shielded cable and 500 amps for unshielded cable.
- Maximum discharge voltage at peak surge current of 100 volts.

The device must quench automatically under normal signal levels. All active or passive loads applied to the signal or control cables must be 13.2 feet (4 meters) or more beyond the point of transient suppressor installation.

Design practices for CMR are not required at the site housing level, but their addition improves protection.

CMR techniques can be applied to signal, control, and antenna cables. Specifications for signal and control cables apply to differential and balancing transformers (table 5-3). For balanced input, a dual spark gap with suitable characteristics should be used. The specifications for each gap of the dual gap are provided above. (188)

4. Antenna

Transient suppressors must be applied to antenna leads operating in the frequency bands below UHF (HF, VHF, etc.). If practical, antenna leads should be brought into the facility envelope through the entry vault. Design objectives are for all antenna lines to be shielded cables and for shields of the cables to be bonded circumferentially to the entry plate. Whatever the antenna shielding, a spark gap transient suppressor must be applied to each antenna lead conductor (excluding shields) carrying signals below UHF. The specifications on the spark gap are as follows.

guidance EMP/HEMP 3. Grounding

- Minimum d.c. voltage rating of 4 times normal operating voltage or 2 kilovolts, whichever is higher.
- Maximum d.c. voltage rating of 8 times normal operating voltage or 5 kilovolts, whichever is lower.
- Minimum energy requirement of 100 kilojoules.
- Minimum rate of rise of 5 kilovolts per nanosecond.
- Maximum firing voltage (impulse sparkover voltage) of 5 times d.c. voltage rating at minimum rate of rise.
- Minimum peak surge current of 2 kiloamps.
- Maximum discharge voltage at peak surge current of 1 kilovolt.

The transient suppressor must quench automatically under normal operating levels. Installation practices for a.c. surge arresters should be followed for systems under 100 kilohertz. For systems higher in frequency, special designs or custom devices must be used to fulfill the requirements of low insertion loss and low surge-arrester impedance. (188)

C. Site

Standard lightning protection is the minimum suppression requirement. Standard distribution lightning protectors are required at the interface of the primary power station with the plant a.c. power transformer. The facility transformer should be delta-wye for a.c. power. Standard transient suppression practices for lightning are required for d.c. power and antennas. Balanced lines and baluns are recommended when applicable for signal, control, and antenna cables. (188)

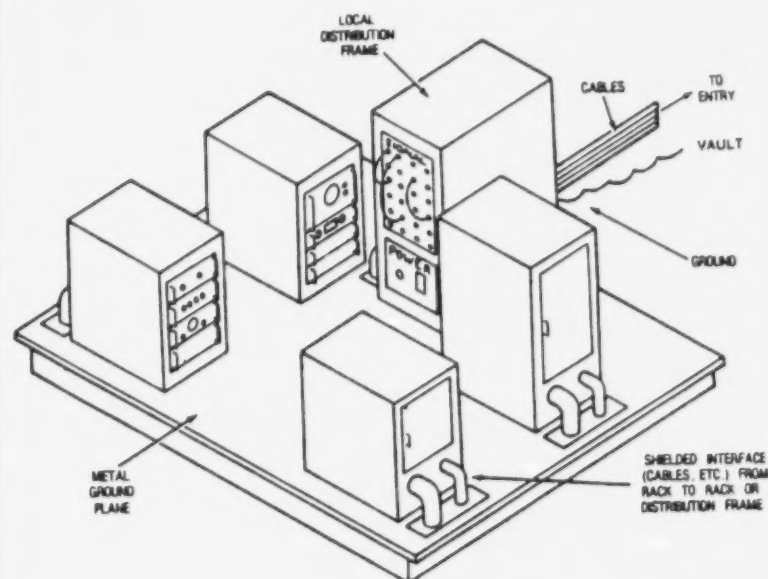
3. a. Spaces**1. Design objectives**

A local multipoint equipotential ground subsystem interconnected to the facility ground system through a single-point connection to the facility ground or earth electrode system is desired. The single-point connection must be achieved through a low-impedance connection to the facility ground system at the entry vault. (188)

guidance EMP/HEMP 3. Grounding

The single-point ground system of MIL-STD-188-124 shall not be used. Single-point grounding is acceptable only if grounds and signal cables are routed together in a tree configuration. The multipoint scheme of MIL-STD-188-124 also is not desirable, as that scheme allows connection to the facility skeletal structure at many locations to effect the multipoint ground. Since the skeletal structure will be driven by the HEMP fields and, most likely, by the penetrator currents, connection to the structure may result in large induced transients on the ground system in the intrasite area. However, the multipoint scheme is preferred over the single-point scheme permitted in the MIL-STD.

The next figure is an example of an acceptable grounding system. It consists of a local multipoint connected system that is single-point connected to the facility ground at the entry vault. (188)



EXAMPLE OF INTRASITE ELECTRICAL CONFIGURATION FOR INTRASITE FUNCTIONAL ELEMENT. (188)

guidance EMP/HEMP 3. Grounding**2. Alternating current power**

The green wire shall be connected directly to the distribution frame at the closest practical point to the wire's entry to the a.c. power area and to the line transient suppression devices in the entry vault. All conduits, trays, and ducts containing a.c. power shall be connected electrically to the distribution frame. The distribution frame will be grounded in the vault area. (188)

3. Waveguide

A design objective is for waveguide entering the the housing to go through the vault distribution frame to the equipment. The waveguide shall be bonded peripherally to a plate on the vault distribution frame. The waveguide shall be grounded by peripheral bonding to the vault distribution frame. If this cannot be done, see reference 188, p 95. The waveguide should then be routed to the equipment using the minimum allowable length. The 12-inch (30-centimeter) isolation distance must be maintained throughout its extent. (188)

4. Grounding

All grounding, bonding, and shielding requirements of MIL-STD-188-124 shall be followed, with major exceptions and additions given in this section.

a. A single-point and multipoint hybrid ground system is a design objective. The system requires an equipotential ground plane local to the interconnected equipment, but single-point grounded to the facility ground subsystem. When two or more equipotential planes are required, they must be grounded to the facility ground subsystem through a star or tree configuration. Communications lines between systems on separate equipotential planes shall follow strict single-point ground control.

b. All cable conductor entries to the interconnected equipment should be through one or more distribution frames that function as "ground windows." A ground window serves to control the routing of all equipment grounds and insures that the potential differences between equipment grounds is minimized. The ground systems should be electrically connected at this ground window when practical. (188)

guidance EMP/HEMP 4. Hardness Testing**b. Facility envelope****1. Alternating current power**

The ground lead for electrical power service shall be connected to the earth electrode subsystem near the entry plate. (188) The high-energy transient suppressors for the site housing entry vault should be installed in the service panel or junction box (the first disconnect means). The most effective ground for the suppressors is provided by a ground stud in the service panel or junction box. The ground wire should be as short as possible and should have no sharp turns or bends. All grounding bonds should be welded, brazed, or made with a clamp approved by Underwriters Laboratory. (188)

2. Direct current power

Grounding and bonding practices for d.c. power cables penetrating the site housing entry panels shall be in accordance with 2b.1 and MIL-STD-188-124. (188)

3. Grounding

All grounding requirements of MIL-STD-188-124 shall be followed for the facility envelope functional element.

c. Site**1. Grounding**

All external grounding requirements of MIL-STD-188-124 shall be followed for the plant exterior functional element. The cable shield of coaxial or shielded antenna leads should be grounded to the mast supporting the antenna and to the entry panel at the facility envelope interface. (188)

4. Hardness testing

Testing should normally be conducted by a crew independent from the construction contractor.

Shielded construction is usually specified to supply a specific attenuation over a given frequency range. The tests to determine if the specifications are met are some type of CW radiated test, MIL-STD-285, NSA 65-5, or IEEE 299. Suppression devices may need to be subjected to some type of pulse injection test to verify their operation under EMP conditions.

guidance**THREAT-LEVEL TRANSIENTS (188)**

Point of entry	Worst-case energy value (decibel joules)
Alternating current power	70
Direct current power	60
Signal cable	50
Control cable	50
Antenna	50
Waveguide	50
Water	25
Sewage	25
Fuel	25
Air-conditioning	25
Grounding	50
Housing structure	0 (per m^2)
Housing apertures	0 (per m^2)

guidance

The set of individual design practices and the alternatives presented for the prime housing volume constitute the minimum requirements to meet the allocated design practice effectiveness for the space (intrasite) zonal element. Specification requirements for the spaces are in the table below and are discussed in section 1.3.4 of reference 188. Transient levels must be reduced to or below the levels specified for the equipment and component functional elements (see ref 188).

SPECIFICATIONS FOR SPACE (INTRASITE) ZONAL ELEMENTS

Point of entry	Energy (dBJ)	Amplitude (kV)	Impedance (ohms)	Rate of rise (kV/ns)	Bandwidth frequency range (MHz)	Wave Shape
Alternating Current power	0	10	100	0.1	1 to 15	Multiple damped sinusoid (MDS)
Direct Current power	0	10	100	0.1	1 to 15	MDS
Signal cable	0	10	100	0.1	1 to 15	MDS
Control cable	0	10	100	0.1	1 to 15	MDS
Antenna	15	100	300	20	0.01 to 100	Double exponential
Grounding	0	2	20	20	0.1 to 10	Double exponential
Housing structure diffused field	-30 (per m ²)	1.6 (per m)	377	10 (per m)	0.1 to 100	MDS
Housing apertures	-30 (per m ²)	1.6 (per m)	377	10 (per m)	0.1 to 100	MDS

guidance

The individual design practices and the alternatives presented for the facility envelope constitute the minimum requirements to meet the allocated design practice effectiveness for the site housing zonal element. Specifications for the facility envelope are in the table below and are discussed in section 1.3.4 of reference 188. Transient levels must be reduced to or below the levels specified for the space functional element.

SPECIFICATIONS FOR FACILITY ENVELOPE (SITE HOUSING) ZONAL ELEMENT

Point of entry	Energy (dBJ)	Amplitude (kV)	Impedance (ohms)	Rate of rise (kV/ns)	Bandwidth frequency range (MHz)	Wave shape
Alternating current power	35	100	100	1	0.1 to 10	Double exponential (xx)
Direct current power	35	100	100	1	0.1 to 10	xx
Signal cable	30	50	100	1	1 to 10	Damped sinusoid (DS)
Control cable	30	50	100	1	1 to 10	DS
Antenna	50	700	300	30	0.01 to 100	xx
Waveguide	30	20	20	1	1 to 10	DS
Water	5	1	20	0.01	0.01 to 10	xx
Sewage	5	1	20	0.01	0.01 to 10	xx
Fuel	5	1	20	0.01	0.01 to 10	xx
Air-conditioning	5	1	20	0.01	0.01 to 10	xx
Grounding	30	20	20	1	0.01 to 10	xx
Housing structure, diffused field	0 (per m ²)	50 (per m)	377	10 (per m)	0.1 to 100	xx
Housing structure, conducted	5	1	20	0.1	1 to 10	DS
Housing apertures	0 (per m ²)	50 (per m)	377	10 (per m)	0.1 to 100	xx

guidance

The individual design practices and the alternatives presented for the site constitute the minimum requirements to meet the allocated design effectiveness for the site zonal element. The specifications for the site are in the table below and are discussed in section 1.3.4 of reference 188. Transient levels must be reduced to or below the levels specified for the facility envelope functional element.

SPECIFICATIONS FOR SITE (PLANT EXTERIOR) ZONAL ELEMENT

Point of entry	Energy (dBJ)	Amplitude (kV)	Impedance (ohms)	Rate of rise (kV/ns)	Bandwidth frequency range (MHz)	Wave shape
Alternating current power	70	10,000	500	500	0.01 to 50	Double exponential (xx)
Direct current power	60	2,000	300	100	0.01 to 50	xx
Signal cable	50	700	300	30	0.01 to 50	xx
Control cable	50	700	300	30	0.01 to 50	xx
Antenna	50	700	300	30	0.01 to 100	xx
Waveguide	50	500	100	20	0.1 to 100	xx
Water	25	10	20	0.2	0.01 to 10	xx
Sewage	25	10	20	0.2	0.01 to 10	xx
Fuel	25	10	20	0.2	0.01 to 10	xx
Air-conditioning	25	10	20	0.2	0.01 to 10	xx
Grounding	50	200	20	20	0.01 to 50	xx
Housing structure, diffused field	0 (per m ²)	50 (per m)	377	10 (per m)	0.1 to 100	xx
Housing structure, conducted	25	10	20	0.2	0.01 to 10	xx
Housing apertures	0 (per m ²)	50 (per m)	377	10 (per m)	0.01 to 100	xx

guidance

guidance

**SB6
Alternative Energy Sources**

References:

1. Military Handbook, MIL-HDBK-412, Site Survey and Facility Design Handbook for Satellite Earth Stations, 20 May 1982.
7. Development of the Basic Design Criteria for the Future Defense Communication System (DCS) Facilities, Volume 1, BDM Corporation, 2 June 1981.
20. Alternative Energy Sources for Federal Aviation Administration Facilities, Federal Aviation Administration, FAA-RD-78-87.

SB6 ALTERNATIVE ENERGY SOURCES (AES)

Policy/SOP	6-4
Requirements	6-6
Guidance:	

LOW POWER AES

1 Photovoltaic Solar Cells	6-12
2 Thermoelectric Generators	6-14
3 Conventional Wind Generators	6-16

MEDIUM POWER AES

1 Wind Turbines	6-17
2 Long-Life Batteries	6-18
3 Flywheels	6-19

HIGH POWER AES

1 Fuel Cells	6-20
2 Small Nuclear Reactor	6-21

ALTERNATIVE ENERGY SOURCES (AES)**function**

Alternative Energy Sources (AES) maintain the electrical power required to operate the technical load at a DCS site as a survivable alternative to more vulnerable commercial power. AES will probably be cost-effective in the 1990s.

policy/sop

1. On-station prime power plants are considered only when the local power is either extremely unreliable, prohibitively expensive, or unavailable, or when self-sufficiency is required for survivability and reliability in a wartime environment. On-station prime power plants normally use multiple sets of DOD standard family, diesel engine generator sets for the power source. Other sources such as wind turbines, thermoelectric generators, fuel cells, gas turbine generators, steam turbine generators, and nonstandard diesel engine generators can also be used and should be considered. An on-station prime power plant will use a minimum of three engine generator sets with one set online and carrying the station load, one set as a standby, and one set as a maintenance spare. A more reliable configuration is to use four or five generator sets with two sets online in a load sharing mode, one as a cold standby unit, and one or two as maintenance spares. (1) 31
2. AES suitability for DCS facilities is determined by power requirements and site.
3. In selecting AES, consideration should be given mainly to internal systems since external systems are more vulnerable to enemy attack or sabotage.
4. Integrated circuit electronics and the trend to lower power use will probably allow the electronics systems to require far less power in the future. (1) 32

policy/sop

5. Available AES systems can be grouped as follows: (20) 77

Low power (less than 100 watts continuous)

- a. Photovoltaic (moving target reflector)
- b. Thermoelectric
- c. Wind.

Medium power (1000 watts to 10,000 watts continuous)

- a. Wind
- b. Fuel cells
- c. Flywheels.

High power (greater than 10,000 watts continuous)

- a. Fuel cells
- b. Small nuclear reactors.

issues and assumptions**1. Alternative energy systems (AES) versus commercial power**

When commercial electric power is available, alternative energy systems (AES) are currently not cost-competitive. (20) 77

2. Selection of AES based on DCS site climate

Two major problems associated with AES are climate and location dependency and decreased system survivability if it must be located outdoors.

Of the 10 AES systems listed below, four are internal (within the facility) systems that are not climate and location dependent. They are--(7) Vol 1, II-50

- a. Fuel cell
- b. Long life batteries
- c. Flywheel power
- d. Small nuclear auxiliary power (SNAP).

The following chart lists the 10 AES that would not be acceptable alternatives in regard to climate and location.

Location	CLIMATE		
	Tropical	Temperate	Arid
Isolated	1,3,4,9	3,4,9	3,4,9
Military	1,4	4	4
Urban/suburban	1,4,6	4,6	4,6

1. Wind generator
2. Thermoelectric generators
3. Solar photovoltaic
4. Tidal power
5. SNAP
6. Hydroelectric
7. Flywheel power
8. Long-life batteries
9. Compressed hydrogen gas
10. Fuel cells

issues and assumptions

requirements	criteria	commentary
LOW POWER AES (approximately 100 watts continuous power). 1. Photovoltaic solar cells	1. Photovoltaic arrays with advanced battery systems for energy storage should be considered the best candidate for powering most 1990 DCS requirements. a. Applications b. Insulation c. Materials d. Power level, size and cost e. Modularity f. Constraints g. Research h. Manufacturers	1. Photovoltaic cell systems are external, and, therefore, highly susceptible to enemy attack or sabotage.
2. Thermoelectric generators	2. The proven technology of the radioisotope thermoelectric generator (RTG) and the fact that military units are already available make the thermoelectric generator a very useful power source for lower powered requirements. The units will work in any location, do not need external fuel, operate in the absence of sunlight, and have an extremely long life on the order of 10 years. They should be the primary candidates for remote, unattended sites. (7) F-15 a. Materials b. Costs c. Advantages d. Constraints e. Availability	

requirements	criteria	commentary
LOW POWER AES 3. Conventional wind generators	3. Energy extracted from the wind is initially in the form of rotary, translational, or oscillatory mechanical motion. This mechanical motion can be used to pump fluids or can be converted into electricity, heat, or fuel. (7) F-2 a. Available output b. Site features c. Costs d. Maintenance e. Back-up system f. Survivability g. System efficiency	

requirements	criteria	commentary
MEDIUM POWER AES (1,000 to 10,000 watts continuous power) 1. Wind turbines with vortex generators	1. Wind power can be used to compress air for various applications, such as operating gas turbines to generate electricity during the peak demand periods of public utility systems. (7) F-3 1. Tradeoffs 2. Maximum output 3. System design	
2. Long-life batteries	2. As previously recommended in the section on photovoltaics, the system best suited for the 1990 DCS requirements appears to be a photovoltaic system backed up with batteries for energy storage. (7) F-51 a. Battery characteristics b. Cost c. Research d. Output e. Containment	

requirements	criteria	commentary
MEDIUM POWER AES 3. Flywheels	3. Though theoretically very appealing, flywheels will probably not be commercialized before 1990. Laboratory prototypes have already achieved the major breakthroughs needed to make the flywheel practical. Notable breakthroughs include magnetic suspension as the bearing system and the brushless motor-generator with the ironless armature. Funding for flywheel research continues at a significantly lower level than that for advanced long-lived batteries. (7) F-42 a. System components b. Storage c. Cost d. Output e. Advantages f. Disadvantages	

requirements	criteria	commentary
HIGH POWER AES (over 10,000 watts continuous power) 1. Fuel cells	1. Because the status of the fuel cell is essentially that of a laboratory device expected to be quite useful in the future, it is not recommended as a primary candidate for powering the 1990 DCS. (7) F-61 a. Efficiency b. System components c. Present applications d. Cost e. Noise impact f. Research g. By-products h. Fuel types i. Modularity j. Advantages k. Disadvantages	

requirements	criteria	commentary
HIGH POWER AES 2. Small nuclear reactors	2. Developments in small nuclear reactors should be studied, as the small size and large power output would allow this power source to provide all of the required power for even the largest DCS unit considered in this study. (7) F-16 a. Reactor core b. Power converter c. Radiators d. Safety and environmental concerns	

guidance LOW POWER AES/1 Photovoltaic Solar Cells**APPLICABILITY TO THE 1990 DCS**

1. By 1990, this will be a very mature technology and a wide variety of modules will be available. It should be possible to purchase off-the-shelf units for standard levels of required power output. Enough information is available now to design a system consisting of the solar arrays and the energy storage system, if the DCS power requirements as a function of time are known. (7) F-29

Photovoltaic cells convert sunlight directly into electricity. Since the output power depends on the radiant energy present in the incoming sunlight, the devices produce an output strongly dependent on their location on the earth's surface, the time of day, time of year, and other factors. The solar constant gives the average value of energy density in sunlight which would be available to a detector positioned just outside the earth's atmosphere. It has a value of 0.1353 watts per square centimeter, which represents an upper limit to the amount of input power density available to a solar cell. (7) F-18

a. Applications

Photovoltaic cells are considered practical for low-power applications (less than 1000 watts continuous). The cells must have an unshaded southern exposure. Cells are generally rated in peak watts. For continuous power requirement, the continuous power output must be multiplied 3 to 10 times, depending on the available insolation.

In most applications, a storage medium must be provided. At present, the only practical, cost-effective method is the storage battery.

Generally, photovoltaic cells are more efficient in cool climates. For each centigrade degree increase in operating temperature above ambient (25°C), the efficiency of the cell decreases approximately 25 percent. (20) B-2

For terrestrial applications, such as that being considered for the 1990 DCS, there will be approximately 12 hours each day without sunlight, so energy storage equipment such as batteries or flywheels must be available to store the energy during the time it is being produced by the solar cells. Many applications already built or planned use inverters to convert the d.c. into a.c. since the solar cell installation is used essentially in parallel with an existing a.c. system. For the 1990 DCS, this will not be necessary since most of the equipment can be powered by d.c. (7) F-19

b. Insolation

Insolation is the total energy/unit area available to a collector at a given spot on the earth's surface, assuming the collector tracks the sun as its relative position changes in the sky. The following table gives typical values of insolation for

guidance LOW POWER AES/1 Photovoltaic Solar Cells

various locations in the United States for collectors which track completely, which track only from East-West, and which are fixed to position. The figure shows that, although simple to construct, fixed collectors have a serious penalty. The data for insolation is for a yearly basis.

EFFECTIVE INSOLATION IN SELECTED CITIES (7) F-19

City	Latitude (°)	Maximum insolation (Tracking collector) (kWh/m ²)	Including weather effects	
			Full tracking (kWh/m ²)	Horizontal collector (kWh/m ²)
Honolulu, HI	21.3	3610	2340	1590
Miami, FL	25.8	3570	2320	1550
New Orleans, LA	30.0	3550	2120	1370
Phoenix, AZ	33.4	3520	3020	1890
Santa Barbara, CA	34.4	3510	2530	1560
Flagstaff, AZ	35.2	3490	2510	1550
Fresno, CA	36.7	3480	2850	1740
Washington, DC	38.9	3460	2040	1210
New York, NY	40.8	3340	2060	1220
Boston, MA	42.2	3420	1980	1150
Burlington, VT	44.5	3370	1680	970
Seattle, WA	47.6	3350	1570	880
Fairbanks, AK	64.8	3030	1450	670

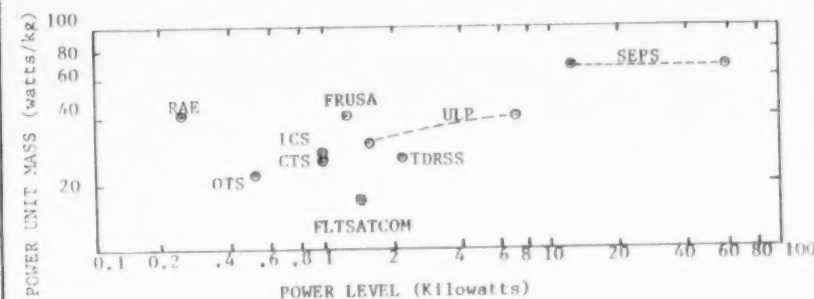
c. Materials

Cells are currently being made with silicon, gallium arsenide, and cadmium sulfate, though many other materials are also being investigated. However, solar cells made from silicon currently dominate the photovoltaic field. Solar cells consist of a junction of semiconductors formed by adding impurities (dopants) to one side of a pure material (homojunction) or joining two dissimilar semiconductors (heterojunction) or joining a semiconductor and a metal (Schottky junction). The combination of materials creates a potential difference across this junction, since each side has different electrical characteristics; excess negative charges (N material) on one side and excess positive charges (P material) on the other side. Light absorption in the semiconductor energizes both types of charges and creates electrical current when the absorbed energy surpasses the material's energy bandgap. Sunlight energy below the bandgap fails to produce current while sunlight energy above the bandgap produces both energy equivalent to that of the bandgap and heat for the excess. A contact grid imprinted to the cell's surface collects the energy flow and channels it to a storage battery or load. Protective and reflective coatings encapsulate the cells which are then placed within glass, plastic, or silicone containers to seal them against the environment. (7) F-20

guidance LOW POWER AES/1 Photovoltaic Solar Cells

d. Power level, size, and cost

Solar cell arrays have found wide use in space power systems. The figure below (from H.S. Rauschenback, Solar Cell Array Design Handbook, Van Nostrand Reinhold Co., New York, 1980) shows typical power levels and specific densities of arrays used on some typical missions.



POWER LEVELS AND POWER/UNIT MASS FOR SPACE MISSIONS.

Present designs for space arrays are aimed at very high power levels (300 to 1000 kilowatts). These designs use optical concentrators to increase the intensity of sunlight falling on the solar cells.

The terrestrial use of solar cells is virtually unlimited with applications as diverse as powering a dust storm warning sign on US-10 to providing potable water and grain milling to residents to Tangaye, Upper Volta. (7) F-21

Another reference (E. L. Burgess, "Photovoltaic System Cost Experience for Intermediate-Sized Applications," Conference Record of the Fourteenth IEEE Photovoltaic Specialists Convergence-1980, Jan. 7-10, 1980, San Diego, IEEE 80CH 1508-1. Institute of Electrical and Electronics Engineering, Inc., 1980) gives a good review of a number of projects ranging up to 330 kW_p (peak) value. The next two tables give the projects described and the size and cost of the photovoltaic arrays being used. Note that both flat plate and systems with optical concentrators are included. (7) F-22

guidance LOW POWER AES/1 Photovoltaic Solar Cells

SYSTEM EXPERIMENTS FROM WHICH PRICE INFORMATION WAS DERIVED

Designation	Location	Application	Size (kWp)	Array type
A	El Paso, TX	UPS	18	Flat Panel
B	Dallas-Ft. Worth, TX	Airport Utility Plant	27	Linear Fresnel Concentrator ¹
C	Albuquerque, NM	Office Building	47	Parabolic Trough Concentrator
D	Kauai, HI	Hospital	85 Concentrator	Parabolic Trough
E	Oklahoma City, OK	Cultural Building	150 ²	Reflector Augmented Flat Panel
F	Lovington, NM	Shopping Center	150	Flat Panel
G	Beverly, MA	High School	196	Flat Panel
H	Phoenix, AZ	Airport Terminal	292 Concentrator	Circular Fresnel
I	Orlando, FL Park	Marine Exhibit	330 Concentrator	Parabolic Trough

¹Actively cooled array.

²Array rating without reflector augmentation is 110 kWp.

PHOTOVOLTAIC ARRAY MODULE PRICES

System	Power level (kWp)	Array area (m ²)	Price (\$/Wp)	Price (\$/m ²)
A	18	263	10.87	744
B	27	245	11.57	1275
C	47	625	9.00	677
D	85	1217	9.38	655
E	150 ¹	1215	11.39 ¹	1406
F	150	2255	9.69	645
G	196	2847	9.26	637
H	292	3310	9.20	812
I	330	3858	8.01	685

¹System is reflector augmented to yield an effective array rating of 150 kWp. Quoted price is an effective price; actual module price is \$15.54 per weak watt.

guidance LOW POWER AES/1 Photovoltaic Solar Cells

Costs have fallen from a constant dollar cost (1980\$) of about \$40,000 to \$50,000 per kilowatt in the early to mid 1970s to the current range of \$7,000 to \$12,000 per kilowatt. Prices are projected to decline still further by the mid 1980s. The DOE goals in constant dollars (1980\$) are:

Year	Module prices (\$/kw-pk)	System prices (\$/kw-pk)	Energy prices (\$/kWh)	Prime application
1982	2,800	6,000-13,000	50-90	Remote
1986	700	1,600-2,200	5.2-8.7	Residence
1986	700	1,600-2,600	5.5-9.2	Intermediate Load
1990	150-400	1,100-1,800	4.2-8.1	Utilities

Beyond 1990, costs may decline still further in constant dollars, but many think the goals cannot be met in the envisioned timeframe. (7) F-23

e. Modularity

The solar cell is essentially a modular system in which multiple units can be connected into arrays of series and parallel arrangements to produce the desired power levels at the required values of load voltage and current. (7) F-24

f. Constraints

Photovoltaic cells generate electrical energy (d.c.) whenever enough sunlight is available. There are no operating constraints as in other power generation or storage technologies. Lifetimes are estimated at 20 years with cell protective containment degradation the limiting factor. The degradation is caused by elevated cell temperatures. The cell maximum operating temperature is about 60°C. Efficiencies range between 6 to 15 percent. Concentrator arrays generally are more efficient because they use tracking mirrors as opposed to the fixed angle, rigidly constructed flat plate cells. The primary reasons photovoltaic cells fail are moisture penetration causing corrosion of contacts, discoloration or degradation of cell encapsulating cover, electrical circuit degradation, cracked cells and cell failure at high temperatures. The only safety problem would stem from exposed interconnections or failure of the physical system support due to weather such as wind. (7) E-27

g. Research

More and more companies are becoming involved in research and/or manufacturing of photovoltaic cells. The oil industry is expending significant money in both their development and manufacturing. Research is primarily examining the basic materials which make up photovoltaic cells.

Research in three materials, polycrystalline silicon, amorphous silicon, and cadmium sulfide promises results in the short term (mid-1980s). Manufacturing techniques using less energy, fewer materials, less expensive materials, material growing techniques as well as attempts to improve theoretical understanding of cell operation and stability are examples of

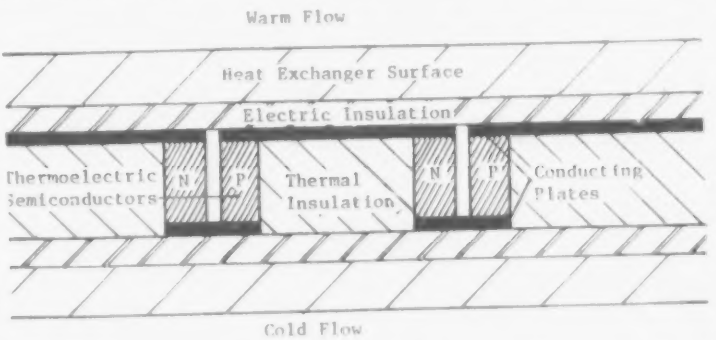
guidance LOW POWER AES/2 Thermoelectric Generators

ongoing efforts to reduce costs and improve efficiencies. Other materials such as gallium arsenide, cadmium telluride, cadmium sulfide/indium phosphide, and zinc phosphide promise to further decrease costs and improve efficiency in the long term. Concentrator systems are also being examined to reduce cell area, allowing the use of higher cost, very efficient cells. (7) F-28

Solar cell technology is a mature, proven field. As the number of applications increases, the very high costs prevailing today will decrease markedly. With increasing fuel costs, they could be very close to being competitive with conventional technology by 1990. Increasing research on batteries will also help with the application of solar cells. Thus, they are very strong candidates to supply power production requirements for the 1990 DCS. (7) F-28

h. Manufacturers

Manufacturers of modules, concentrator solar cells, concentrator modules, or power systems include: AAI Corp, Acurex Corp, Applied Solar Energy Corp, Arco Solar, Arizona Scientific Research, Automatic Power, BDM Corp, E-Systems, General Electric, Martin-Marietta, Microwave Associates, Motorola, Photon Power, Photowatt International, Rockwell International, Science Applications, SES, Silicon Sensors, Solar Electric, Solar Kinetics, Solar Power Corp., Solarex, Solec International, Solectro Thermal, Sol-energy Corp, Sollos, Spectrolab, Spire Corp, Sun Trac, Thermal-Electron, Tideland Signal Corp, United Energy Corp, Varian Associates, Westinghouse Electric Corp, and Zomeworks. (7) F-28



TYPICAL THERMOPILE

APPLICABILITY TO THE 1990 DCS

2. Thermoelectric generators

Thermoelectric generators are devices which directly convert heat to electricity. The process is based upon the "Seebeck

guidance LOW POWER AES/2 Thermoelectric Generators

Effect," which was discovered over 160 years ago, that occurs when two dissimilar materials are electrically connected and the junctions are maintained at different temperatures. The Seebeck coefficient, (T) , is temperature dependent and gives, for a particular combination of materials, the ratio of open-circuit voltage produced to the temperature difference between the two junctions. (7) F-10

a. Materials

The most useful materials for thermoelectric generating elements, defined as thermoelements, are semiconducting materials. By using P and N type semiconductors it is possible to produce a combination which will have a larger Seebeck coefficient. When these are combined, the device is known as a thermopile. A typical arrangement is shown in Figure 2. Note that the input heat is required to maintain the hot junction at its desired temperature. The conversion efficiency of a thermopile is defined as the ratio of the output electrical power produced to the input heat power required. Typically, the conversion efficiencies of thermoelectric generators are in the range from 6 to 11 percent. (7) F-11

Thermoelectric materials currently include bismuth telluride, lead telluride, the selenides, and alloys of silicon-germanium. Each of these materials has a best operating temperature range and conversion efficiency, which is temperature dependent. A high figure of merit is obtained for those materials which possess a high Seebeck coefficient, a high electrical conductivity and a low thermal conductivity. (7) F-11

b. Costs

The cost of bismuth telluride thermoelectric material will probably decrease as the demand increases and a unit cost of \$2.60 per pound (1978 \$) could be expected for a demand of 10^5 pounds and an increase in demand to 10^6 pounds would reduce the unit cost of \$1.04 per pound (1978 \$). (7) F-12

c. Advantages

Some advantages of thermoelectric systems are that they have no moving parts and have a long service life requiring little maintenance. Being essentially modules, the desired level of electrical power output can be achieved by using multiple modules in the required series-parallel combinations needed to produce the required voltages. (7) F-12

Units up to approximately 100 watts are available. Weight is a restriction. A 100-watt unit weighs more than 4000 pounds.

Thermoelectric generators are particularly useful for remote or inaccessible locations where constant, continuous, electrical power is required for long periods (years) without refueling or

guidance LOW POWER AES/2 Thermoelectric Generators

maintenance. By amortizing the initial cost of a thermoelectric generator with a radioisotope heat source over a period of its life, the cost per kilowatt-hour is still significantly higher than the use of fossil fuels. (20) B-4

d. Constraints

Radioisotope Thermoelectric Generators (RTGs) are inherently low-voltage, high current devices; hence most of these will require the use of dc to dc voltage converters or power conditioners to convert the voltage to the level and type required by the application. Some power conditioners are internal and integral to the RTG design; others are external. Although RTGs are expensive, the only costs are the initial cost, transportation, and installation. Modules can withstand severe environmental and temperature conditions. Continuous heat removal is required to prevent damage to thermoelectric elements. (20) 39

There are a number of ways to provide the heat required to maintain the hot junction at the desired temperature including solar ponds, ocean thermal gradients, focused solar collectors, nuclear reactors, or radioisotopes. The nuclear heat sources have been primarily used in space missions and are described by the acronym "SNAP", meaning Small Nuclear Auxiliary Power. The radioisotope sources are RTGs and the nuclear reactor sources are called "SPAR" for Space Reactor Power Supply. There has apparently been some development by the military for terrestrial application. Reference (G. Guazoni, A. Herchakowski and J. Angello, "Military Thermoelectric Power Sources," Proceedings of 13th Intersociety Energy Conversion Engineering Conference, Society of Automotive Engineers, 1978) describes U.S. Army development activities in 100 watt and 500 watt thermoelectric power sources. The heat source for these two units is a burner which uses hydrocarbon fuel. The 100 watt and 500 watt Army generators have dimensions and weight of 37 centimeters by 20 centimeters by 36 centimeters, 13 kilograms and 48 centimeters by 63 centimeters by 53 centimeters, 30 kilograms, respectively. (7) F-13

e. Availability

The RTGs which are currently available have specific weights on the order of 2.9 to 3.4 watts per pound and an advanced generator produces 286 watts in a canister 24 inches in diameter and 32 inches high which weighs about 84 pounds. The radioisotope heat sources use plutonium dioxide (PuO_2) pellets encased in an iridium shell. Four of these pellets are contained in a graphite case of approximately 4 by 4 by 2 inches which weighs about three pounds. This unit is designated as a general purpose heat source and produces approximately 275 watts. These heat sources are designed as modules and can be stacked to produce the desired amount of thermal power.

Because these are radioactive devices, very stringent design conditions are put upon RTGs by space missions to ensure the in-

guidance LOW POWER AES/3 Conventional Wind

tegrity of the fuel pellets at launch, during a mission abort, during a mission, and upon reentry in the earth's atmosphere. For terrestrial applications, some of the design requirements pertaining to operation on a space mission could probably be relaxed.

Nuclear reactors are being planned for missions with larger electrical power requirements, of the order of 100 KW_e. A design constraint, which would not be present in a terrestrial application, is that the nuclear reactor source, the thermoelectric generator, and the heat radiator must fit into the cargo area on the shuttle. The dimensions of a 1200 KW_t solid fuel reactor with heat pipes used to transfer the heat of the thermoelectric generating elements are shown in Table 4.

DESIGN PARAMETERS FOR A NUCLEAR REACTOR TO PRODUCE
POWER BY THERMOELECTRIC CONVERSION

Reactor Power (kw _t)	1100	Total Reactor mass (kg)	440
Core diameter (mm)	310	Fuel region	165
Number of core heat pipes	90	Reflector	150
Core heat pipe temperatures (K)	1400	Heat pipes	60
Reactor diameter (mm)	550	Control system	35
Reactor height (mm)	530	Support structure	30

3. Some of the most effective applications use energy derived directly from the wind, without further energy processing, conversion, or storage. However, wind-derived energy can be converted to other forms of energy or can be stored through the use of compressed fluids, pumped-hydro systems, water-saver systems, batteries, hydrogen, flywheels, or hot water. Some energy is normally lost in each of these conversion or storage steps.

Wind energy is one of the most flexible and tractable of all available energy sources, since the mechanical energy derived directly from the wind can be readily and efficiently converted to other forms of energy. The efficiency of converting wind-derived mechanical energy to heat or electrical energy is usually much higher, for instance, than the efficiency of converting solar or fuel-derived heat energy to mechanical or electrical energy since the efficiencies that can be attained when converting heat to mechanical or electrical energy are limited by the relatively low Carnot cycle efficiencies, which, even under optimum conditions, usually do not exceed 20 to 35 percent. (7) F-2

a. Available output

In wind systems, output is usually stated in terms of rated power. For a continuous power requirement, a factor of 5 to 10 times the continuous power should be applied, dependent on available winds at the location. Wind speeds near the earth's surface generally increase as the 1/7 power of the height above the earth. To determine tower height, a cost analysis of increased

guidance LOW POWER AES/3 Conventional Wind

tower height versus increased windspeed must be made. Wind shear and consequently the available wind power is affected by the roughness of the earth's surface in a given location. This means buildings or trees, for example, at a given site can create wind shear problems. Streamlines of a windstream are compressed and flow is accelerated as it passes over a hill or through a narrow valley. Average power output may be increased by proper siting to take advantage of these anomalies. (20) B-2

b. Site features

The features of a suitable site are: (20) B-2

1. High annual average windspeed
2. No tall obstructions upwind for a distance depending on the height of the tower
3. Top of a smooth well-rounded hill or flat plain or island in a lake or sea
4. Open plain or open shoreline
5. Mountain gap that produces a funneling effect

c. Costs

Costs involved are: (20) 3

1. Wind turbine
2. Tower
3. Storage batteries
4. Power conditioning equipment
5. Transportation costs
6. Periodic maintenance

d. Maintenance

Wind generators require annual maintenance and have approximately a 20-year service life. (20) 15

e. Back-up system

Wind generators usually require a back-up system if the wind turbine output falls below the average load requirements. (20) 19

f. Survivability

A wind system is an external system and therefore highly sus-

guidance MEDIUM POWER AES/1 Wind Turbines

ceptible to enemy attack, sabotage, or severe environmental conditions, but has the advantage of being nonpolluting and requires no fossil fuel except for a back-up system. (20) 20

g. System efficiency

At wind speeds lower than the rated value, rotor speed must vary with the wind speed to extract the maximum possible power, thus not matching the optimum operating conditions for either synchronous or induction a.c. generators, if these types of generators are being driven by the wind machine rotor. This mismatch problem has led to several interesting concepts for interfacing the rotor with its electrical output. One approach is to allow the rotor speed to vary optimally with the wind speed and to employ a variable-speed constant-frequency generating system to obtain the constant-frequency power needed for an electric utility grid. Both differential (e.g., mechanical or electrical frequency changing devices) or nondifferential (e.g., static frequency changers or rotary devices) may be used to accomplish this. (7) F-6

1. Wind turbines

Conventional gas turbines can be modified to separate the compressor, generator, and power stages by clutches. In one mode of operation, the motor-generator, operating as a motor and powered by a wind machine, drives the air compressor. The compressed air is fed into a storage tank or into a large cavern, aquifer, or depleted natural gas well. Under this mode, the power turbine is inoperative, and no fuel is consumed.

In a second mode of operation, when the demand for power exceeds the supply of the base-load utility system, the compressor is disengaged, and the power turbine is connected to the generator. The burner that drives the power turbine is fed fuel and compressed air from storage to generate power for the utility system.

The temperature of air is raised when it is compressed without loss of heat (i.e., adiabatic compression). If the air is stored in a well-insulated high-temperature container it will retain most of its heat (i.e., isothermal storage). Adiabatic storage is obviously better, from the standpoint of energy conservation, than isothermal storage. (7) F-3

Wind-powered pumps can also be used to save fuel and electricity by compressing the working fluids used in heat pumps for space-heating applications.

a. Trade-offs

There are significant trade-offs to be considered in the design of wind turbines. Turbines with a small total blade area

guidance MEDIUM POWER AES/1 Wind Turbines

will maintain a high volumetric flow rate of the airstream, but the pressure drop will be relatively small, and the resulting power output and power coefficient will be small.

For turbines with a large total blade area, the change in pressure and the reduction in windstream velocity will be large, but the volumetric flow rate of the windstream will be low, resulting in a low power output and a low power coefficient.

The optimum total blade design, therefore, maximizes the product of the volumetric flow rate and the pressure drop across the turbine. (7) F-5

b. Maximum output

The torque developed by a horizontal-axis rotor blade of a fixed pitch angle varies with both the shaft speed and the wind velocity. If the rotational speed of a blade is too slow in a windstream of a given velocity, the blade will stall, and the output torque of the wind machine will decrease. Therefore, to develop maximum power output from a windstream, as the speed of the windstream varies, either the pitch-angle of the blade or the rotational speed of the blade must be varied. Many of the more modern wind machines are designed with variable-pitch blades. For these, a control mechanism can be provided that will adjust the pitch of the blades to maintain a constant rotational speed as the wind speed changes or the output load varies. (7) F-6

c. System design

Ducted systems using wind concentrators and diffusers can increase the wind speed through the turbine by a factor of 1.5, compared to the free-flow wind speed, and produce up to 3.5 times the power generated by an ideal wind turbine having a diameter equal to that of the ducted turbine and operating at the same ambient free-flow wind speed. Specific designs have to be analyzed to determine if the additional power output outweighs the cost of the diffuser. In general, inlet ducts or entry cones have not been found to be very effective, whereas exit diffusers are still the subject of considerable research. Both unconfined and confined vortex generators that spin in the wind to increase the power output of a turbine located in or near the vortex are being studied. Unconfined vortex systems are under examination at both the Polytechnical Institute of New York and West Virginia University. Such systems use wing-like structures to deflect the wind and to create an unconfined vortex around the turbine. Such systems might be designed to provide up to six times the power output of a conventional wind machine with the same rotor diameter, located in a freely flowing windstream with the same wind speed as the unconfined vortex system.

A confined vortex system is being developed by Grumman Aerospace Corporation, in which the pressure drop across a ducted turbine, and the wind speed through it, are further enhanced by using

guidance MEDIUM POWER AES/2 Long-Life Batt.

additional ambient wind to generate a confined tornado-like vortex in a tower located at the exit of the duct.

Such confined vortices can be created by a variety of structures designed to collect the wind over a wide area and spin it as it enters an enclosure, such as a tower, with a helical or circular cross-section, interconnected to the exit of the duct in which the turbine is located.

These concepts are expected to provide guidance for further research in developing significant improvements in wind machines of this type in a wide range of sizes; i.e., from a few kilowatts up to perhaps several hundred megawatts. Because of their enclosed high-speed turbines of relatively small diameters for a given output power, they might be more suitable for siting in an urban area than the large-diameter, horizontal-axis wind turbine generators that are designed to operate in ambient windstreams. (7) F-8

2. Long-life batteries

Advanced long-life batteries will probably be commercially available in the 1990s. Even if developments in these batteries are not accomplished by that time, the advances made in the conventional batteries of today, namely lead-acid and nickel-cadmium, will provide systems with the required attributes for the 1990 DCS power requirements. Note that careful system design optimizes the photovoltaic and energy storage system for the expected demand of the DCS. (7) F-51

a. Battery characteristics

Batteries will most likely be nickel-cadmium or one of many exotic high-energy-density batteries currently being developed, as opposed to the common lead-acid battery. (29) 50-55

Batteries used for a storage system should meet the following guidelines: (20) 51

1. Deep discharge capability
2. Long cycle life
3. Fast recharge capability
4. High reliability with minimum preventive maintenance
5. Satisfactory operating capability in a wide range of environments.

b. Cost

Batteries are an energy storage device for either the long or short term. Lead-acid batteries, the state of the art for long

guidance MEDIUM POWER AES/2 Long-Life Batt.

life batteries today, cost about \$75 per kilowatt hour (1981 \$). The price of lead fluctuates with the price of gold and is a significant part of the cost of the lead acid battery. Advanced battery research was started to increase battery life (charge-discharge cycles) and because of the large potential demand for batteries. Demand would drive up the price of lead-acid batteries; lighter weight batteries are also desired for electric cars. Some anticipated users are: cars powered by batteries, photovoltaic systems using batteries as back-up for nights and cloudy days, and energy storage devices for electric utilities to level their system load. Batteries could be charged at night and other low load times using less expensive hydro, coal and nuclear energy and then discharged during a utility's peak system demand instead of using gas turbine generators using expensive oil or natural gas. The goal for battery costs is a stable price of \$60 to \$80 per kilowatt hour, the same real price (1981 \$) as today's lead-acid batteries.

Lead-acid batteries cost about \$75 per kilowatt hour. Meanwhile advanced batteries commercially would cost up to \$450 per kilowatt hour. However, costs in the years 1990 to 2010 for advanced batteries should decrease to the \$65-\$95 range in real terms (1981 \$), depending on many factors such as technology verification, demand, and commercialization. Lead-acid batteries could increase in price dramatically. (7) F-50

c. Research

Long-term research (1990 and beyond) aims to develop and prove new battery designs with substantially longer lives and components with lower costs than lead. Current battery lives range from about 150 to 2,000 charge-discharge cycles. Long-term battery goals specify lives of 20 years requiring thousands of charge-discharge cycles since they could cycle daily. The industry is directing efforts at three battery types in the short-term: Lead-acid, Nickel-iron, and Nickel-zinc.

Manufacturers are also examining Zinc-Chlorine, Redox, Zinc-Bromine, Sodium-Sulfur and Lithium-Sulfur as advanced battery concepts. The first three operate at ambient temperature but require moving electrolytes or membranes to separate the electrodes while permitting ions to pass through. The latter two operate like conventional batteries but require high temperatures (300 degrees centigrade to 400 degrees centigrade). (7) F-46

d. Output

Today, the range of power outputs is quite large. The years 1990 to 2010 should see energy-capacity densities increasing by a factor of 2 to 5 which would also decrease their size substantially. Today, batteries are grouped to provide a rather large range of power outputs. This range will be increased to the 20 megawatt size or greater. Advanced battery modules should have a power output range of 50 to 400 kilowatt hours per module. (7) F-50

guidance MEDIUM POWER AES/3 Flywheels**e. Containment**

All batteries will need to be housed in a shelter which controls the climate. Some batteries will require very tight temperature controls while others can stand wider temperature swings. But some control may be needed to stop exposure to temperature extremes. Efficiencies today are 60 to 65 percent and should improve up to possibly 90 percent in the 1990s. (7) F-50

3. Flywheels

Flywheels are an energy storage system serving the same purpose as a battery though with several striking differences. They convert electrical energy to mechanical energy and efficiently store it for days, weeks, or months. Then, when required, the flywheel will convert the energy back to electrical energy. In order to achieve high efficiency at reasonable sizes and costs, flywheels need to reduce losses (both frictional and electrical) and to achieve rather fast spin rates. Since the energy stored in a flywheel varies not with the mass of the spinning system but, also and more significantly, with the square of the rotation speed, it can store much more energy with high strength light-weight fibrous material than with a high strength steel. Faster rotational speeds account for this. (7) F-38

a. System components

The flywheel has four basic parts, a rotor to store the energy, bearings to reduce frictional losses, a containment structure to house the flywheel, and a motor-generator to convert a.c. electrical energy to mechanical energy as well as mechanical energy to a.c. electrical energy. The rotor is typically made out of a very high tensile strength, lightweight, fibrous material such as Kevlar which was designed by Dupont for the space age and automobile tire applications. The bearings are a magnetic suspension system which virtually eliminates friction. To eliminate the air drag, the containment structure creates a vacuum. To protect property and personnel in proximity to the flywheel, the containment structure must either be a very strong material, thick enough to protect against an exploding rotor or sufficiently strong enough to only maintain a vacuum and be placed underground. The motor-generator is within the containment structure and a part of the flywheel itself. It is a brushless unit with a rotating magnetic field that reacts against a stationary armature wiring to produce torque. Also there is no iron in its fiberglass armature, which reduces electromagnetic drag, thus increasing the efficiency. The flywheel rotor is homopolar since there is no flux reversal between pole pairs. MIT's Lincoln Lab has developed electronic circuitry designs, though not exclusively limited to its application, which will convert d.c. to a.c. more efficiently and at less cost than today's conversion equipment. (7) F-39

guidance MEDIUM POWER AES/3 Flywheels

For stand-alone applications, two sizes are being considered: 20 kilowatts and 40 kilowatts. These sizes are dictated by the potential market and are not constrained by the technology. (7) F-40

b. Storage

Current energy density storage is in the realm of 10 to 20 watt hours per pound. Goals for 1990 and beyond are 60 to 70 watt hours per pound. A present-day residential application of 40 kilowatt hours would require a 3-foot diameter, two-ton, magnetically suspended flywheel underneath a house. This should be reduced to 600 to 700 pounds in the 1990s. (7) F-40

c. Cost

There are no cost figures for flywheels today because only laboratory prototypes exist. But based on cost estimates, which MIT had consultants calculate, producing 10,000 stand alone systems per year in 1985 would cost between \$215 to \$275 per kilowatt hour in 1980 dollars. These figures were based on full-scale systems capable of storing 40 kilowatt hours, a maximum power input or output of 10 kilowatts, and a 2700 pound rotor. Cost projections for the years 1990 to 2010 are difficult to make and will probably stay in the same \$215 to \$275 range in 1980 dollars. Essentially, no further breakthroughs are anticipated. The soft magnets in the motor-generator are Samarian Cobalt which as a rare metal would track the price of gold. Three of the four basic components, the rotor, magnetic bearings, and containment structure would not see any dramatic price changes and would probably track the producer's price index. The only area which could possibly see a significant price reduction would be the motor-generator. That reduction could only take place if a more common material were to replace the Samarian Cobalt magnets. (7) F-41

d. Output

Operating speeds for a flywheel range between 9,000 to 15,000 revolutions per minute. Though the flywheel is contained in a vacuum chamber, about every 3 months maintenance personnel would have to pump back the vacuum. Though state of the art welded seals for vacuums are highly reliable, material can outgas. Operating ambient temperatures could range between -40 degrees centigrade to +60 degrees centigrade. Above 60 degrees centigrade flywheels would lose efficiency at the rate of one-half percent per degree centigrade increase in temperature. Burying the flywheel in the ground could alleviate the high ambient temperatures. The efficiency of the stand-alone module is estimated to be about 75 percent overall for absorbing electrical energy, storing it as mechanical energy, and reconvert it to electrical energy. No dramatic improvements in efficiency are anticipated. (7) F-41

guidance HIGH POWER AES/1 Fuel Cells**e. Advantages**

- Flywheels are non-polluting
- Flywheels have the potential to store more energy per pound than batteries
- Flywheels are noiseless
- Flywheels can be left unattended for up to 3 months
- Flywheels can be placed anywhere

f. Disadvantages

- Rotor could explode if it reaches too high a rotational speed
- Current plans call for a relatively long recharging time of 4 to 8 hours though it could be designed to recharge instantly.

(7) F-42

1. Fuel cells

By 1990, fuel cells will probably be in the same position that thermoelectric and photovoltaic systems are today, i.e., they will have been used in a number of systems and some of today's problems will have been solved. However, they are inherently more complicated than either thermoelectric or photovoltaic units and require the use of a fuel to produce the required electrical power. Developments in the fuel cell area should be closely monitored, though, as they do provide some advantages which could be used in the next generation of DCS requirements. (7) F-61

a. Efficiency

Fuel cells are a means of transforming fuel into electrical energy at very high efficiency (about 50 percent) compared to conventional power plant efficiencies of 15 to 30 percent. Fuel cells act as the opposite of hydrolysis, in which two electrodes are inserted in salt water and a voltage is applied across the electrodes causing hydrogen and oxygen to be given off. The fuel cell functions with hydrogen reacting at the anode to form electrons and positive ions. The electrons pass through the external circuit (load) to the cathode. The ions pass through the electrolyte to complete the circuit. At the cathode, the electrons, ions, and oxygen combine to produce water. Though invented 140 years ago, they were developed for use in the Gemini and Apollo spacecraft. (7) F-56

b. System components

Today's fuel cell has four basic parts. The first is the chemical processing plant and heat exchangers which convert the fuel to hydrogen gas plus a residual gas. Second is the fuel cell stack which takes the hydrogen gas and combines it with oxygen to generate d.c. electrical energy, water, carbon dioxide, and residual heat. The third component is the overall structure and parts which integrate the fuel cell stack, heat exchangers, and fuel processing plant. Fourth is the solid state power condi-

guidance HIGH POWER AES/1 Fuel Cells

tioning equipment which converts electrical energy from d.c. to a.c. The chemical processing plant mixes a fuel with high temperature steam and passes the mixture over a catalyst to produce hydrogen and carbon monoxide. The temperature varies with the fuel used. A typical temperature for methane would be 1500 degrees Fahrenheit. Steam at a lower temperature (900 degrees Fahrenheit) is then used to mix with the hydrogen and carbon monoxide gases to convert the carbon monoxide to carbon dioxide. The fuel cell stack then takes these gases and consumes most of the hydrogen; electrochemically oxidizing it to water. Air is generally used as the oxidizing agent. The overall structure consists of heat exchangers, plumbing, and pumps to regulate the flow of fuel and heat. A boiler converts water to steam for the fuel processing. Finally d.c. to a.c. inverters are used since most electrical energy use requires a.c. (7) F-57

c. Present application

Fuel cells are primarily being developed for the electric utility industry where they would be placed in substations to operate unattended. They would be periodically maintained. The Army is also looking at them for small power sources. The Army wants a small, disposable can-sized fuel cell that would be simple, reliable, and rugged. To simplify the fuel processing, they envision bottles of hydrogen. In addition, work has been done on fuel cells for use in transportation. (7) F-57

For electric utilities, 5 megawatts and greater sizes are envisioned. For the Army, significantly smaller sizes are desired, probably less than a kilowatt. The size of the transportation units is in the 10 to 100 kilowatt range. However, there is no inherent limitation on power output so demand will determine their range. (7) F-58

d. Cost

Fuel cell cost will depend greatly on its intended application. The first application is for use as a power plant. Fuel cells are not commercial today, so first unit prototypes are expensive (about \$4,000 per kilowatt) - such as the one in New York City. Of that, about \$2,000 is for the fuel cell stack. The remaining \$2,000 is evenly split between the remaining 3 parts. Projections, assuming substantial commercial production in 1985, estimate the cost of fuel cells to be about \$500 per kilowatt (1981 \$). Of that, the breakdown would be: fuel cell (\$150), chemical processing plant (\$75), stack integration equipment and heat exchangers (\$75), solid state power conditioner-d.c. to a.c. (\$55), and the rest of the site ancillary equipment (\$145).

In the second application fuel cells replace fully charged batteries for mobile, stored energy in sizes less than a kilowatt. The fuel processing plant would not be needed since bottles of hydrogen would probably be used. The Solid Polymer Electrolyte (SPE) is the unit probably closest to commercialization and those

guidance HIGH POWER AES/1 Fuel Cells

prices could range between \$20 to \$200 per kilowatt hour depending on whether the catalyst is zinc or lithium. Projections by the Army anticipate fuel cells in commercial production to have capital costs for small units at about \$25 per watt and energy costs about \$8 per kilowatt hour (in 1981 \$). (7) F-58

e. Noise impact

Fuel cells will be quiet if operated as a power plant with the only noise coming from the boiler and pumps used in processing the fuel. Since they are inherently simple, maintenance should be low and reliability high. For the small, rugged fuel cell battery applications envisioned by the Army and the National Oceanic Atmospheric Administration (NOAA), the units will be small (less than a kilowatt), but completely maintenance free, disposable containers. The lifetimes are questionable at this time. (7) F-59

f. Research

Significant research is being conducted by a variety of manufacturers. Funding, besides that from the manufacturers, comes from EPRI, Department of Energy, and Department of Defense. Japan may be spending more money in fuel cell research than the U.S. and could well commercialize it before the U.S. Current fuel cells primarily use phosphoric acid as the electrolyte. However fuel cells are short-lived and there are problems with corrosion. Research is directed at increasing the life of the cell and eliminating the corrosion.

Fuel cells are considered practical for medium and high power (greater than 10,000 watts continuous). Efficiencies of fuel cells range from 37 to 40 percent. Planned technological advancements forecast efficiencies in the 50 to 60 percent range. Fuel cell efficiency remains nearly constant from partial to full load conditions. Fuel cells must be sized to meet peak load requirements. (20) B-3

g. By-products

Heat is a by-product of the fuel cell. Recovery of this heat for heating and cooling through the use of a heat pump or similar device would further increase the efficiency of the fuel cell. (20) B-3

h. Fuel types

Fuel must be supplied to the fuel cell. Some fuel types are: methanol, ammonia, hydrogen, propane, and natural gas. Therefore, fuel availability, storage, and cost must be considered. (20) B-3

i. Modularity

Fuel cell systems are modular and portable. A system con-

guidance HIGH POWER AES/2 Small Nuclear Reactor

tains 3 modular sections: processor, fuel cell stack, and a power inverter (dependent in load requirements). This modularity lends itself to direct replacement and very little onsite repair. (20) 22

j. Advantages

- Fuel cells have no moving parts
- Waste products are water, heat, and carbon dioxide; all non-toxic
- A fuel cell is not limited by the Carnot cycle where the efficiency is limited by the temperature difference between input to the machine and its exhaust
- Fuel cells create no noise (though the boilers and pumps for making steam to convert fuel to hydrogen make some noise)
- A fuel cell maintains the same efficiency at all power levels (conventional power plant efficiency varies widely with output power level)
- Fuel cells are mechanically simple

k. Disadvantages

- Not yet commercial
 - costs are uncertain though estimated to be low
 - reliability is uncertain though theoretically very good
- Possible to poison an electrode or catalyst with an impurity in the fuel or oxidizer.
- Short expected stack life (1 to 2 years continuous operation)
- Must not freeze a fuel cell (electrolyte changes phase) (7) F-61

2. Small nuclear reactors

Small nuclear power programs for space in the late 1970s were to develop nuclear space power for the Department of Defense and satellites proposed by NASA for the 1980s. In this program three different technologies were examined that were able to encompass power generation requirements from a few hundred kilowatts to several kilowatts. The three areas of emphasis were radioisotope/static, radioisotope/dynamic, and reactor/dynamic.

Radioisotope/static generators range in size to several hundred watts. They offer significantly higher efficiencies, lower weights and lower costs. These generators should be available in the early 1980s. The basic concept is electricity generation by thermoelectric materials which are heated by plutonium-238.

Radioisotope/dynamic generators also use Plutonium-238 as a heat source. In these generators the heat produces high-temperature gases which in turn drive a turbine alternator. These generators are cost-effective in the .5 to 5.0 kilowatt range.

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guidance HIGH POWER AES/2 Small Nuclear Reactor

Reactor/dynamic generators are suitable for power levels of 10 to 100 kilowatts or more. This technique may produce electricity at a cost of \$100 per watt or lower in the larger sizes.

The disadvantages of the radioisotope/static power sources are their relatively high cost per watt and their weight. They have been proven to be reliable and effective in numerous satellite and space probes. In the next few years, improvements may reduce the costs to \$10,000 to \$7,000 per watt. Additionally, weight may be reduced to 4 pounds per watt by the mid 1980s. Other improvements in power source materials will increase their efficiency in the next several years.

The reactor/dynamic generator is under development at Los Alamos Scientific Labs. It is a high-temperature, compact, fast neutron reactor which will probably be available in the late 1980s. Flexibility and modularity are being taken into account in its design. (7) F-34

a. Reactor core

Zirconiumhydride added to a uranium-fueled reactor has been tested but temperature limitations of 975 degrees centigrade make the system bulky and complex. Higher temperature reactors fueled by materials such as uranium carbide, zirconium carbide, uranium dioxide molybdenum cermet, molybdenum encapsulated uranium dioxide, and uranium nitride would significantly decrease power plant weight and volume. Reactor core exhaust temperatures of 1675 degrees centigrade and lifetimes of 7 to 10 years are possible by the mid-1980s. (7) F-35

b. Power converter

The Department of Energy and the National Aeronautics and Space Administration (NASA) have funded extensive work on power conversion systems for the radioisotope and heat pipe plus thermionic power programs. Silicon-germanium thermoelectric technology appears to offer up to 50 kilowatts electric power with little risk, and selenides now being developed may extend the useful range of thermoelectrics to nearly 100 kilowatts. A dynamic Brayton cycle system can be used at higher power levels; a Brayton converter has been operated more than 26,000 hours without maintenance and with no wear or failure noted during inspections that would prevent a five-year lifetime. Thermionic converters being developed by the Energy Department and NASA should be demonstrated at 20 percent efficiency in the early 1980s. (7) F-35

c. Radiators

Technology is well-developed but heat pipe radiator usefulness must be assessed. Higher temperatures planned with thermoelectric converters will reduce radiator size and alleviate prob-

guidance HIGH POWER AES/2 Small Nuclear Reactor

lems with folding or roll-up radiators. Brayton converters require lower temperatures and therefore need larger radiators to achieve high cycle efficiencies. The Brayton converter would probably be larger but would use more conventional materials. (7) F-35

d. Safety and environmental concerns

The greatest concern about the application of these generators for DCS facilities revolves around safety and environmental hazards. Presently no provision has been made to use these sources in manned vehicles. All applications have been for unmanned space vehicles. Certainly any application of these power generators near inhabited areas or near areas with wildlife must be critically examined. Apart from the question of the personal safety of inhabitants near a site is the question of the safety and safe operation of the reactor itself. These generators have been hardened to withstand the harsh environments due to spacecraft launch, but a ground system must also be concerned with equipment malfunctions from seismic action. The long lifetime of these reactors is attractive, but many issues must be addressed before they can be used for DCS operations. (7) F-36

SB7
Security Systems

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SECURITY

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SECURITY SYSTEMS**function**

The building site must withstand intrusion by individuals or groups intending to compromise the security of information transmitted and received at DCS facilities.

policy / s o p**1. Priorities**

Resources shall be allocated to insure physical security at DCS mission essential facilities. Resources (funds, personnel, and material) shall be allocated between facilities by the operating commands to insure security of these facilities as a first priority. Allocation of resources at a given site shall be based on the systematic analysis of threats, susceptibilities, and feasible security measures. (9) 4.1.2

Upon establishment of the required physical security program, it is the operating command's responsibility to conduct the required training for security program effectiveness. (9) 4.1.4

2. Site size

The physical size of a communications facility determines in large measure the feasibility and the cost of providing adequate physical security. In general, every effort shall be made to reduce the area(s) encompassed by DCS facilities to eliminate requirements to secure unnecessary terrain but still implement adequate security measures. When a DCS facility occupies a large area, efforts shall be made to subdivide essential facilities into zones providing requisite levels of protection. (9) 4.1.5 The process of dividing a site into security zones is described in 7 below.

3. Inspection

The physical security program shall include inspections of the physical security plan and the actual implementation of physical security measures. Security inspections shall be scheduled to provide formal inspections on a yearly basis, with more frequent informal inspections as the local mission and threat dictate. Security program and system inspections shall be done within 30 days after the completion of any site modifications that affect the physical security equipment or procedures. (9) 4.1.6

4. Intelligence

Operating activities shall establish and maintain close and frequent liaison with local intelligence units, intelligence units supporting the operating command, military police, and security forces that have

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jurisdiction in the area of the site. Operating activities shall establish and maintain a record or log documenting attempts or actual incidents of vandalism, unauthorized entry to sites, sabotage, or surveillance conducted against a site. Intelligence, counterintelligence, and supporting security units shall be informed of all such incidents. (9) 4.1.7

5. Foreign national sovereignty

DCS facilities outside the United States may be on property not under U.S. sovereign control. The implementation of security measures at such sites may be limited by status-of-forces agreements between a host nation and the United States. Operating activities shall review terms of relevant agreements to determine the limitation of security practices that may prevail in a host country. Operating activities shall insure that all latitude available in status-of-forces agreements is used in preparing physical security program plans. Operating activities shall insure that no physical security measure is implemented that conflicts with local status-of-forces agreements.

Operating activities shall coordinate with local area or theater commanders and with U.S. Consulate officers to determine the relevant terms of status-of-forces agreements. (9) 4.1.8

6. Security program requirements**General**

A security program is required for each site within the DCS. These programs shall be tailored for each individual site and shall consist of at least the following activities: threat assessment, determination of site susceptibilities, evaluation of site criticality and endurability requirements, determination of suitable security measures, and a plan for the allocation of resources to accomplish the security program objectives. (9) 4.2.1

Threat assessment

The threat posed against a given DCS facility depends on the facility's geographical location, the political and economic environment in the area, and the facility's function in varying scenarios. The operating activity shall determine, in combination with the proper intelligence support agency or detachment, the nature and capabilities of the threat to a site. A profile of the threat shall be developed for each site. This threat profile shall identify, in as much detail as necessary, the persons, groups or organizations, and foreign agents who constitute a probable threat. The threat profile shall contain enough detail on threat organization, training, equipment, and motivation to permit an evaluation of the probable effectiveness of candidate security measures. The profile shall consider the threat posed by vandals, consider the scenarios of peacetime and prehostility tension. (9) 4.2.2

policy / s o p**Site susceptibilities**

These are ways the facility may be damaged to cause loss of facility function. Each DCS facility requires the continuous function of specific operations such as power generation or conversion, signal transmission and reception, and data processing. Disruption or loss of a single such operation leads to loss of ability and mission failure of the site. Through use of site operational flow diagrams, fault tree analyses shall be performed to identify the failure modes of a given facility. The identified failure modes shall be compared with the actual physical layout and integration of the site to arrive at site susceptibilities. (9) 4.2.3

Site criticality and durability requirements

Each individual facility within the DCS serves a different mission, which varies with the location, scenario, subscribers served, kind of communication media involved, and degree of redundancy in the network. The operating activity, in coordination with the DCS, shall perform a mission analysis to arrive at a statement of site criticality and site durability requirements. The statement of criticality shall be used to prioritize the allocation of physical security resources. The site durability requirements shall be used to choose and evaluate the effectiveness of the tailored site physical security program. (9) 4.2.4

Allocation of resources

Operating activities shall prepare a plan for allocating available resources to provide physical security at each site. The allocation resources plan shall cover both the installation and operational phases of the site security program. The plan shall consider financial, material, and personnel resources. Portions of the plan requiring the provision of services or responses by security or military police shall be coordinated and approved by such police units. (9) 4.2.6

7. Security measures**Concept**

The overall approach to providing security at DCS sites consists of five elements: intrusion deterrence, intrusion detection, alarm assessment, component and physical plant hardening, and security or response force personnel. The intrusion deterrence element should provide a psychological state of mind to a potential intruder that an intrusion will result in unacceptable counteraction. The intrusion detection element should provide an alarm to the operating activity or security personnel that an unauthorized intrusion has occurred at a DCS site. The alarm assessment element should verify that an intrusion alarm was activated by a threat against the DCS site. The component hardening

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element of the physical security system should delay damage or limit the amount of damage inflicted on a site. The security force element should delay, stop, or mitigate the intruder's actions. Every DCS site security program shall be prepared to include the five elements of the security system. (9) 4.3.3.1

Physical security measures

The physical security system for a DCS site may consist of a combination of passive and active measures coupled with response by reaction forces. (9) 4.3.3.2

Passive measures

Passive security measures are those which do not consume energy after their initial installation. Included are fences, barriers, revetments, walls, and hardening measures that delay or deter intruders. (9) 4.3.3.2.1

Active measures

Active physical security measures include sensors and other devices requiring the consumption of energy after installation or involving human activity for effectiveness. Active measures may deter or delay an intruder. Examples are intrusion sensors, protective lighting, smoke or other obscurants, and sprays and foams. (9) 4.3.3.2.2

Reaction forces

These include guards, security personnel, or operators whose purpose is to intercept or delay an intruder through the use of force, including lethal force. (9) 4.3.3.2.3

Procedural security measures

These include human activities that have been planned or implemented to enhance or complement physical security measures. Examples are site entry control, alarm assessment procedures, on-site weapon control, and guard force duties. Procedural security measures are generally those directives issued by a local commander to effect best use of security resources at a given site. (9) 4.3.2.3

8. Depth in defense concept**Concept of security zones**

The protection of a DCS site shall consist of implementing security measures, both physical and procedural, within each of five separate areas that together encompass the entire site and its immediate surroundings. These areas and their boundaries constitute security zones as defined below. (9) 4.3.3.4

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Definition

Security zones are continuous regions, delineated by boundaries, that surround the components and equipment to be protected. Each site is composed of five security zones (zones 0, 1, 2, 3, and 4). Boundaries between security zones will, in most cases, consist of barriers that impede the progress of intruders. The actual sizes of security zones are a function of the individual site. The following two figures show examples of security zones at generic DCS sites. (9) 4.3.3.4.1

Rationale

Security measures are implemented using the concept of security zones to produce a defense-in-depth for the protection of a DCS facility and to facilitate the assessment of security effectiveness by providing well-defined zones for the use and evaluation of physical protection. (9) 4.3.3.4.2

Application

Security measures shall be applied to each of the five security zones resulting in a defense-in-depth consisting of a number of distinct countermeasures that an intruder must defeat in sequence to reach the intended target. Defense-in-depth is achieved by siting concentric sensor systems and barriers so that they successfully detect an intrusion and delay the intruder long enough for interdiction by an appropriate response force.

Impact

Security measures applied to each security zone shall have one or all of the following effects:

- a. Provide intrusion deterrence by producing an obstacle, real or imaginary, to a potential intruder.
- b. Increase intrusion delay by increasing the time required for the intruder to penetrate barriers to reach the intended target and by burdening the intruder with special or added equipment needed to penetrate the barrier.
- c. Facilitate intrusion detection by effective placement of sensors.
- d. Facilitate alarm assessment by providing well-defined regions for visual or audio interrogation of sensed intrusions.
- e. Enhance effectiveness of security forces by increasing the probability of intrusion detection and by providing enough intrusion delay to allow an effective and timely response to intrusion. (9) 4.3.3.4.4

policy / s o p

Characteristics

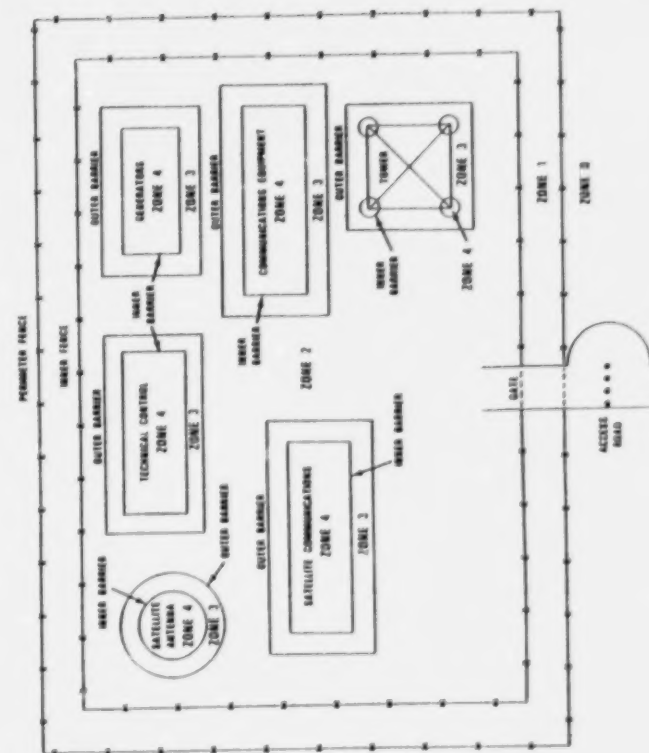
The following characteristics apply to security zones:

- a. Security zones shall be numbered, with the highest zone number corresponding to the most secure region of the facility.
- b. Each security zone shall consist of a continuous region surrounding the components and equipment to be protected.
- c. Adjacent zones shall have zone numbers that differ by not more than one.
- d. There may be more than one security zone with the same zone number, provided the preceding condition holds.
- e. All sites shall have five security zones.
- f. The number and location of security zones are independent of the threat.
- g. Security barriers will consist of fences, reinforced concrete barriers, walls, domes, and special reinforced concrete or metal sleeves.
- h. Security measures used for security zone boundary openings (gates and doors) shall be commensurate with those applied to the zone boundary. 4.3.3.4.5

Variability

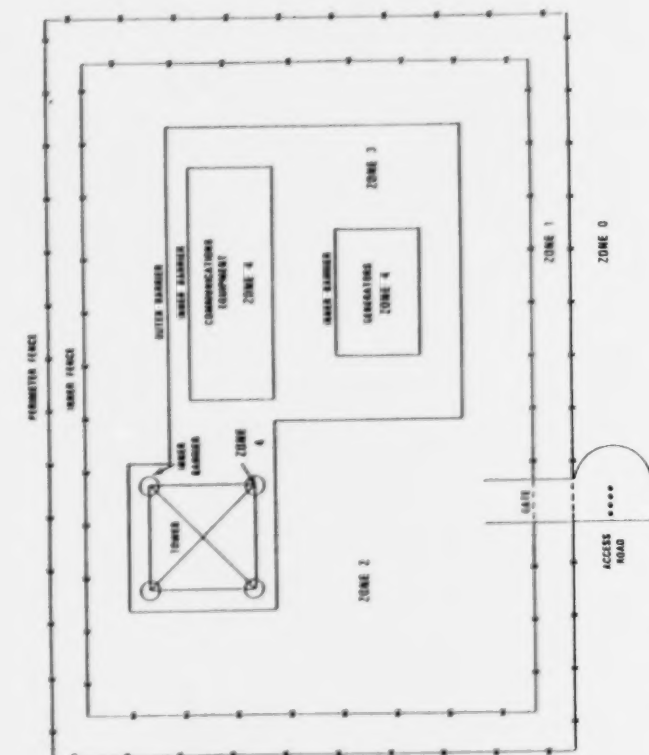
Physical barriers should be used to delineate security zones. However, some facilities may not have enough physical barriers to delineate five zones as defined above. For example, there may be only one perimeter fence at a site because of too little area. At sites for which not enough barriers can be implemented, the five zones shall be delineated by the barriers possible and by imaginary boundaries located approximately where the missing ones would have been placed. Additional physical and procedural security measures shall be implemented on or near the existing barriers commensurate with the levels of deterrence, detection, or delay that would have been provided by the missing barriers. This procedure insures that all DCS facilities will have five security zones for implementing physical security measures, regardless of the number of physical barriers available. It also insures that the level of protection afforded a site with too barriers is commensurate with that for a site with physical barriers delineating all five zones. (9) 4.3.3.4.11

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EXAMPLE OF SECURITY ZONES FOR A GENERIC MANNED DCS SITE

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EXAMPLE OF SECURITY ZONES FOR A GENERIC UNMANNED DCS SITE.

issues and assumptions

1. Determination of appropriate security measures

The security measures to be implemented at a given site are to be determined on a case-by-case basis. The factors to be considered are threat, site susceptibilities, site criticality, and endurability requirements. The methodology for systematic consideration of these factors is given in subsequent sections of the standard in (9) 4.2.5.

2. Site classification: generic versus unique

All communication sites and associated facilities identified with the DCS, whether government-owned or leased, can be categorized as either generic or unique. Many sites are similar in their size, shape, and topography of terrain occupied. Further, the communications facilities and equipment are often identical. As a result of efforts to standardize site layouts and equipment, DCS sites tend to be similar and compact. The "generic" and "unique" classifications are therefore used for planning and implementing physical security programs.

Generic site

This is a communications site containing all elements of signal reception, processing, and transmission with provisions for emergency power. It is contained in a single parcel of land occupying an area of 2 acres or less and is not occupied by other noncommunications tenants or operations. (9) 3.22

Unique site

This is a communications site that does not qualify as a generic site. Examples include an underground communications site, a building occupied jointly with other, noncommunications activities, or facilities occupying more than one distinct parcel of land. (9) 3.58

The operating activities shall determine whether a site is generic or unique using the definitions of such sites given above, along with other considerations that may be appropriate. If a site can be classified as generic, the procedures and methods for physical security protection given in this section shall be applied. If a site is classified as unique, special procedures will be applied as directed. (9) 4.3.2

3. Determining deterrence effectiveness

The deterrence value or effectiveness of a specific security measure or combination of measures is not quantifiable. However, trained security managers can judge the deterrence effectiveness of specific measures against certain threats (for example, vandals or demonstrators) on the basis of experience at similar sites or at other facilities using similar measures. When no experience base is available, security planners should assume security measures provide no deterrence to a dedicated terrorist or saboteur. (9) 5.3.7.1
Vulnerability analyses can be made.

issues and assumptions

4. Determining delay effectiveness

In general, most security measures provide some delay in the execution of damaging acts against a DCS facility. Delay effectiveness of a given security measure is quantified in terms of the additional time an intrusion or act of sabotage requires due to the presence or implementation of a given security measure. The additional time may be due to the need for stealth, time needed to bypass or penetrate a barrier, or time needed because additional equipment, weapons, or explosives must be carried. (9) 5.3.7.2 Security planners should assess the effectiveness of security measures alone and in combinations to arrive at the maximum possible effectiveness expected for a given set of security measures. (9) 4.3.4.1.2

5. Factors influencing choice of sensors

No single sensor is available that detects all possible methods of intrusion into zone 1 and that has an acceptable false alarm rate for the variety of site conditions found at DCS sites. Two or more sensors may be required to achieve a desired detection ability along with an acceptable false alarm rate. Each DCS site is unique in terms of characteristics that influence the choice of exterior intrusion sensors. No single sensor or combination applies to all DCS sites. The choice of sensors shall be made after establishing the detection objectives of the zone 1 sensors and assessing all factors that can influence the decision. Assistance in the final choice and installation of zone 1 sensors shall be obtained from the U.S. Air Force Physical Security Systems Directorate, Hanscom Field, Bedford, Massachusetts. (9) 5.1.3.3.6.1

6. Lighting as a deterrent

The Federal Government has sponsored several investigations to address the issue of lighting as a deterrent. Two agencies, the National Bureau of Standards (NBS) and the National Institute of Law Enforcement and Criminal Justice (NILECJ), have executed or sponsored research to determine if security lighting has a deterrent effect. Two NBS studies tested the deterrent effect of perimeter lighting and concluded that security lighting has only a deterrent effect on the opportunistic intruder (for example, the vandal or prankster). The NILECJ-sponsored research investigated the relationship between street lighting and crime. The results of this research are uncertain. The paucity of reliable and uniform data and the inadequacy of available evaluations thus preclude a definitive statement on the relationship between street lighting and crime. There is no statistically significant quantitative evidence that street lighting affects the level of crime, especially if crime displacement is taken into account. There is a strong indication that increased lighting decreases the fear of crime, however. In spite of the lack of conclusive evidence for the deterrent value of security lighting, there is a genuine reluctance within the security community to dismiss deterrence as a design objective of security lighting. (37) 13.1-124

requirements	criteria	commentary
1. Secure zone 0	1.a. Zone 0 consists of the region outside the perimeter fence and typically contains the following elements: 1. Cleared land outside the perimeter fence 2. Access road 3. Parking lots 4. Commercial power lines 5. Guy wires b. Alarm assessment and deterrence	
2. Secure zone 1	2.a. Zone 1 includes the perimeter fence and the region between that and an inner fence. Zone 1 ordinarily contains the following elements: 1. Perimeter fence, gate, and locks 2. Cleared area between perimeter and inner fence 3. Warning signs 4. Sensors b. Deterrences and detection of intrusion	

requirements	criteria	commentary
3. Secure zone 2	3. a. Zone 2 includes the inner fence, and the area between that fence and the outer barriers needed to protect towers, antennas, power sources, and electronic equipment. Zone 2 may contain the following elements: 1. Inner fence, gates, and locks 2. Sensors on the inner fence 3. Perimeter lighting 4. Closed-circuit television 5. Communication cables 6. Fuel storage 7. Fuel lines 8. Air-conditioning b. Intrusion detection and improved alarm assessment (9) 4.3.3.4.8 c. Alarm reporting systems	
4. Secure zone 3	4. a. Zone 3 includes the outer barriers and the area between outer and inner barriers needed to protect towers, antennas, power sources, and electronic equipment. Zone 3 ordinarily contains the following elements: 1. Outer barriers (walls) 2. Area between the outer and inner barriers 3. Waveguides 4. Antennas and antenna feeds b. Intrusion delay and building penetration resistance 1. Walls 2. Roofs/floors 3. Doors 4. Windows 5. Utility openings 6. Hardware	

requirements	criteria	commentary
5. Secure zone 4	5. a. Zone 4 includes the inner barriers needed to protect towers, antennas, power and fuel sources, and electronic equipment along with the area within those barriers. Zone 4 may contain the following elements: 1. Inner barrier 2. Area within the inner barriers 3. Towers and tower legs 4. Guy wires and guy-wire anchors 5. Electronic equipment 6. Power and fuel sources b. Intrusion delay to protect the "critical" assets 1. Vaults: conventional construction 2. Vaults: penetration resistance	
6. Signal shielding (TEMPEST)	6. The term "TEMPEST" flags the system as one that processes national security-related information. This establishes the need for additional, site-specific facility alterations to prevent compromising emanations and security measures. a. Delineation of interior levels of security b. Shielding, filtering, and isolation	6. See, Vol 2, SB4, Grounding, Bonding, and Shielding.

guidance SECURITY/1 Zone 0**1.a. Zone 0 security measures**

Security measures in zone 0 are installed to deter and detect vehicular intrusions and to enhance visual alarm assessment. (9) 5.1.3.2

1. Cleared land outside the perimeter fence

An extended cleared area at least 9 meters wide shall be maintained outside the perimeter fence through the use of chemicals or routine ground maintenance. The cleared area shall have no obstacles, topographical features, or vegetation greater than 20 centimeters high. When possible, topographical features and obstacles shall be removed to permit visual or enhanced visual (binoculars) assessment of access road sensor alarms. (9) 5.1.3.2.4

If not limited by site boundary restrictions, an extended clear area (a minimum of 30 feet), should be maintained on each side of the perimeter fence to prevent cover and concealment of an intruder. Clear zones should be free of all obstacles, vegetation, and topographical features more than 8 inches high.

The level of illumination at a distance of 30 feet beyond the outer fence should be adequate to enable visual detection of persons by security guards or the operation of electro-optical (imaging system) or other electronic devices under various weather conditions.

Perimeter clear zone light intensity shall be a minimum of 4 lux* measured on a horizontal plane at ground level. Entry point lighting shall be a minimum of 15 lux covering the area from the inner fence to a point 15 meters outside the perimeter fence gate. The lighting level at critical points of site must be 20 footcandles minimum. (9) 5.4.2.8

2. Access road

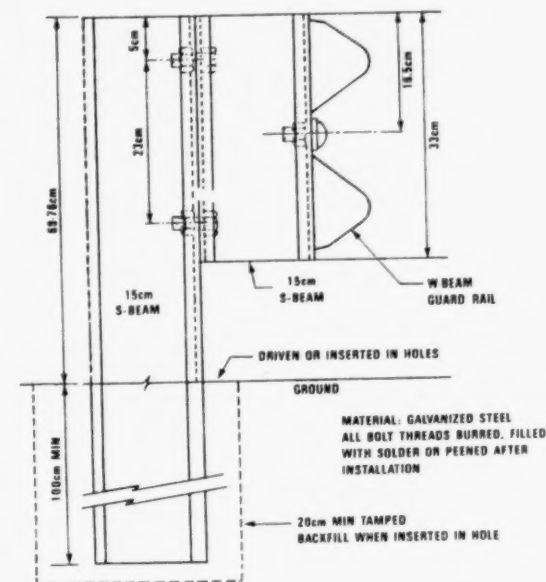
For security, the number of access roads to DCS facilities shall be kept to the minimum needed for efficient operation of the site. (9) 5.1.3.2.1

All access roads shall be lined continuously with vehicle barriers from the nearest adjacent road to the site perimeter fence gate. Vehicle barriers shall not be used alongside an access road if the terrain immediately adjacent to the road precludes the use of four wheel drive vehicles to circumvent

*1 footcandle = 10.76 lux.

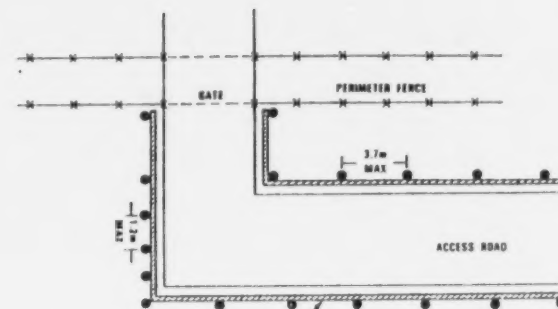
guidance SECURITY/1 Zone 0

the road. Vehicle barriers also shall not be used to line the access road at facilities where the site perimeter is less than 60 meters from an adjacent road or where the surrounding terrain offers alternative approaches to the site for four wheel drive vehicles. Vehicle barriers shall be placed to prevent straight-line approaches by vehicles to the perimeter fence or perimeter fence gate. These barriers shall be placed such that authorized access to a site by emergency or maintenance vehicles is still available. (9) 5.1.3.2.1.1

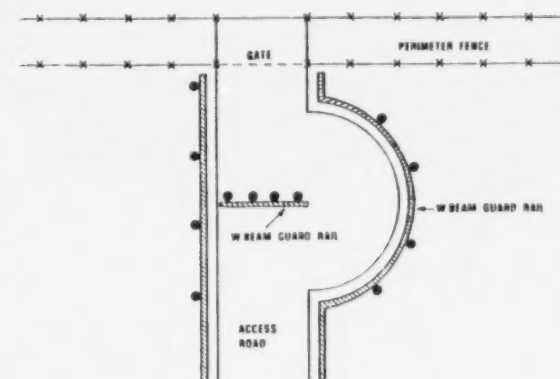


VEHICLE BARRIER. (78) 132

guidance SECURITY/1 Zone 0



Note: Posts on embankment placed min. 10 cm from edge.



VEHICLE BARRIER. (33) 130

Vehicle barriers such as steel crash barriers, tire puncturing strips, or "King Tut" blocks can limit vehicle access to critical facilities. Access roads layouts to meet security objectives, such as 90 degree turns to prevent high-speed runs at barriers, serve the same purpose. (37) 13.1-117

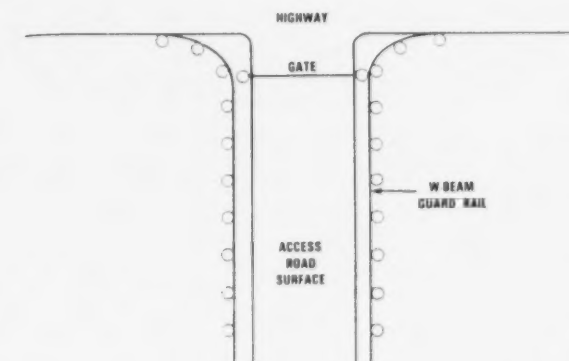
guidance SECURITY/1 Zone 0

Entrance--Entrance to site access roads shall be restricted by a vehicular control gate. This gate shall be offset a minimum of 10 meters from the adjacent road. A vehicular control gate shall not be used at facilities for which the site perimeter is less than 60 meters from an adjacent road or for which the surrounding terrain offers alternative approaches to the site for four wheel drive vehicles. The vehicular control gate at unmanned sites shall remain locked at all times, with the following exceptions:

- If a maintenance crew is on site, the gate shall be closed but not locked to allow free passage of emergency vehicles, should the need arise.
- If the first response unit to a site intrusion does not have the ability to unlock the gate, the vehicular control gate shall be closed but not locked.

At manned facilities, the vehicular control gate shall be closed except during periods of heavy traffic (for example, shift changes) and during normal visit and delivery times. The vehicular control gate at manned facilities shall not be locked to allow free passage of emergency vehicles. The vehicular control gate at both manned and unmanned DCS sites shall be posted with a warning sign. (9) 5.1.3.2.1.3

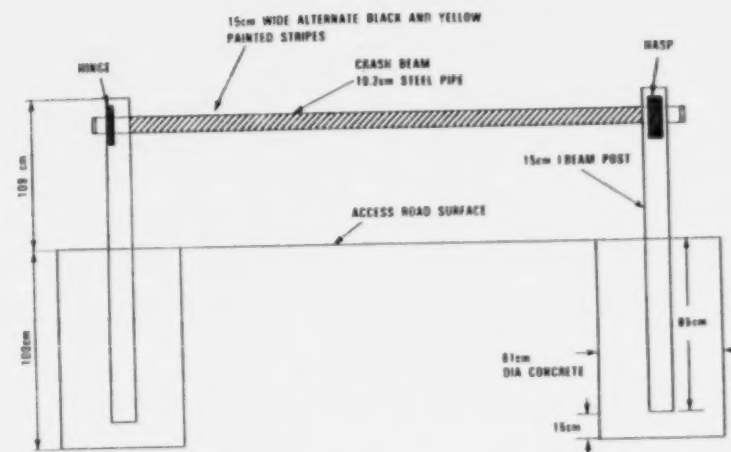
Entrance control--Access through the vehicular control gate shall be controlled using the site entry control procedures specified in "Zone 1 security measures." (9) 5.1.3.2.1.4



VEHICLE BARRIER. (78) 133

DCA CIRCULAR 300-95-1

guidance SECURITY/1 Zone 0



VEHICLE CONTROL GATE. (78) 135

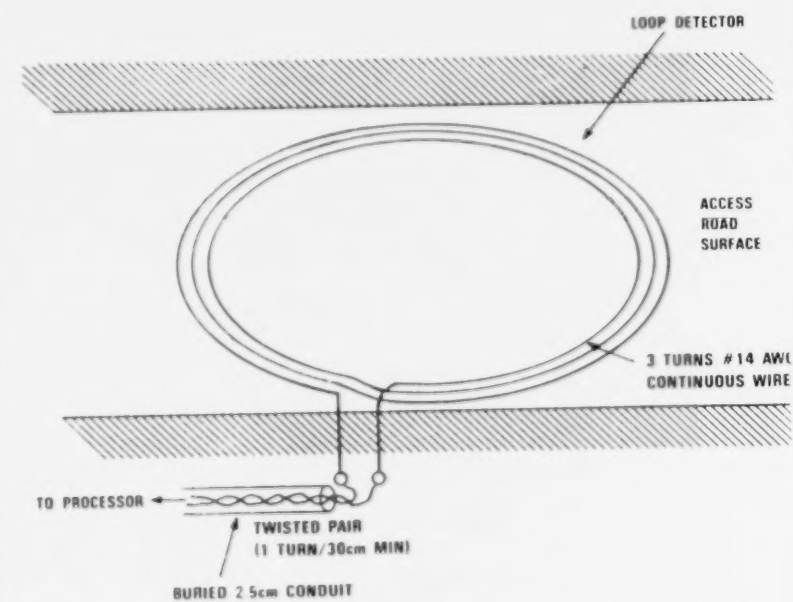
Vehicle approach routes to a DCA facility must be minimized. Additionally, vehicular access to the site should be limited to one gate that is secure and controlled. This gate must be offset a minimum of 10 meters (35 feet) from any adjacent or approach road. Vehicle barriers shall line the access road continuously except where the adjacent terrain prohibits four wheel drive vehicles approach to the perimeter fencing. Entry gate location and approach designs should inhibit vehicle acceleration. (9) 5.1.3.2.1

A gatehouse is required when a military guard is posted at the perimeter entry gate. Additionally, a guardhouse may be required for visual surveillance at critical sites. Both should include:

- Armored protection
- Security communications
- Duress alarm
- Firing ports
- Lighting control.

guidance SECURITY/1 Zone 0

Sensors--An access road sensor shall be used at all DCS facilities to sense vehicles approaching the site. This sensor shall not be used without a vehicular control gate that will preclude sightseeing or casual traffic from tripping the sensor. At unmanned facilities, the sensor output shall trigger an audible alarm on site as well as at the facilities charged with alarm assessment and response force dispatch for the site. At unmanned sites, the sensor shall not be deactivated at any time. At manned facilities, the sensor output shall trigger an audible alarm on site only. The alarm shall not be deactivated unless the vehicular control gate is opened to accommodate heavy traffic. (9) 5.1.3.2.2



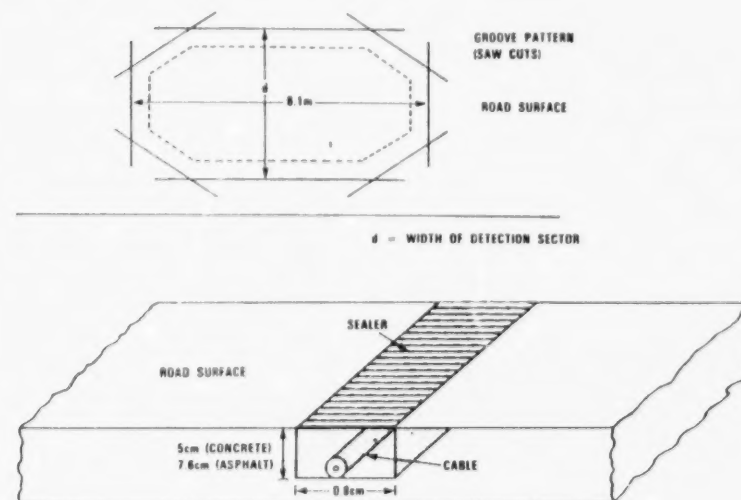
ACCESS ROAD SENSOR. (78) 137

guidance SECURITY/1 Zone 0

Description. The access road sensor may consist of an active loop detector buried in the access roadway as indicated in the figure below. When an approaching vehicle crosses the roadway wire loop, the vehicle's metal changes the loop inductance, producing an alarm. (9) fig. 5

Installation. The access road sensor wire shall be placed at the bottom of a saw cut and laid in the slot so that there are no kinks or curls, and no straining or stretching of the insulation. All loops shall be wired in a counter-clockwise direction. The wire shall be tamped with a wooden stick in a way that will not cut it. Any wire with cuts, breaks, or nicks in the insulation shall be replaced. The wire shall be installed so that each loop is pressed to the bottom of the slot and against one another. Saw cuts shall be made in accordance with the figure shown below and overlapped so the slot has full depth at all corners. All corners shall be rounded smooth. (9) fig. 5

Maintenance. Periodic performance testing shall be done. If the sensor is suspected of degraded performance, testing shall be initiated. (9) fig. 5



ACCESS ROAD SENSOR. (78) 138

guidance SECURITY/1 Zone 0**3. Parking lots**

Vehicle parking at manned DCS facilities shall be more than 10 meters outside the site perimeter fence. Vehicle barriers shall be placed around parking lots to prevent vehicular access to the perimeter fence. No vehicles shall be permitted within the site perimeter fence except those authorized for supply and maintenance. No civilian vehicles shall be permitted within the site perimeter fence. (9) 5.1.3.2.1.2

Private vehicles should be parked in a designated area outside the perimeter fence, within view of the gate guard. Vehicles should not be authorized to park within 30 feet of a secure area or adjacent to critical components. Military vehicles should be secured inside the perimeter fence and should not impede the view of the perimeter.

4. Commercial power lines

Cables--All power, communications, and sensor cables entering the site and on site shall be buried at least 90 centimeters. The locations of all buried cables shall be obscured. When practical, cables shall enter the site by diverse routes. All manholes and cable vaults on site shall be locked. Off site, all power cables shall be buried at least 600 meters away from the site. As a minimum, all manholes within that 600-meter range shall be locked. (9) 5.1.3.2.5

Both regular and standby battery power must be provided for intrusion detection system (IDS) and security lighting. In some cases, dual emergency backup power may be required, particularly if power transformer stations are vulnerable.

All critical power, communications, and IDS lines should be well protected, usually by burial. Cabling for light poles should be internal to the aluminum or steel poles. Standby power sources must be protected from sabotage by facility hardening and IDS coverage. Standby power sources should be configured for automatic activation when required.

5. Guy wires

guidance SECURITY/1 Zone 0

b. Alarm assessment and deterrence

An alarm triggered by the access road sensor indicates the presence of a vehicle on the road or inside the closed vehicular control gate. This vehicle will be authorized and hence predicted according to the site entry procedure or it will be unauthorized. At unmanned facilities, a response force shall be dispatched upon an access road sensor alarm for an unauthorized vehicle's presence. If a maintenance crew is on site, visual assessment may be used to cancel the response action if warranted. At manned facilities, prompt visual assessment of an unauthorized vehicle shall be made, if possible, upon an access road sensor alarm. If prompt visual assessment is not possible, for example, at a site with a long access road, a response force shall be dispatched upon access road sensor alarm. (9) 5.1.3.2.3

Exterior barriers are to discourage low-motivation intruders so that only high-motivation intruders set off enough alarms to constitute a valid warning. (9) 3-2

Perimeter lighting can be used to deter unauthorized entry and to help detect intruders. Lights should be positioned within the site and along the entire perimeter. They should be configured and arranged to provide illumination adequate for personnel identification at the entry control point areas immediately surrounding the site.

One function of security lighting is to provide light during periods of darkness and low visibility, aiding observation by security personnel, or to permit an IDS to function. Lighting also may have value as a deterrent to nondedicated intruders. Normally, security lighting uses less candle power than working area lighting, except at ports of entry. Security lighting is used to increase effectiveness of guard systems and closed-circuit television by increasing the visual range of the guards and CCTV monitors during periods of darkness, or by increasing illumination of an area where natural light does not reach or is not enough. Exterior security lighting is advisable only to insure a minimal level of visibility when guards are positioned properly to perform inspection duties around the exterior. Guards and CCTV monitors must be able to see badges and people at gates, inspect vehicles, stop attempts at illegal entry, detect intruders inside and outside buildings, and observe unusual or suspicious circumstances. Each facility presents its particular problems based on physical layout, terrain, atmospheric conditions, and security requirements. Exterior lighting should not be routinely specified for physical security, but should be considered an option and compared to other types of lighting for detection and deterrence. (37) 13.1-120

guidance SECURITY/2 Zone 1

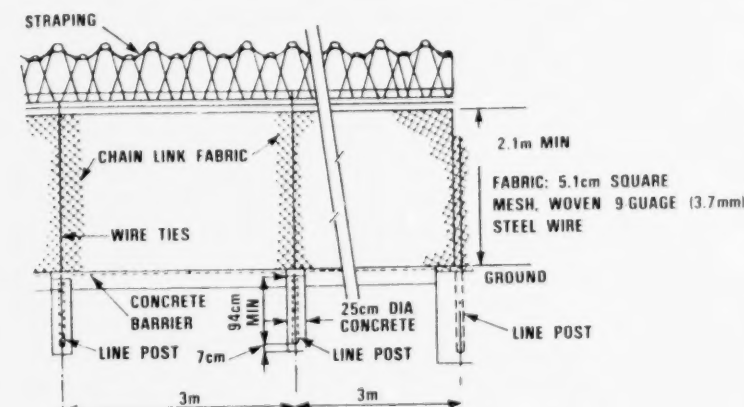
Perimeter lighting should be designed to enable detection of persons throughout the region bounded by the inner perimeter fence to 30 feet outside the outer perimeter fence. New lighting fixtures should be installed no closer than 8 feet inside the inner (or single) perimeter fence. At least 25 percent of the perimeter lighting should be protected from small arms fire.

2. a. Zone 1 security measures

Security measures are installed in zone 1 to provide intrusion deterrence and detection and to enhance alarm assessment. (9) 5.1.3.3

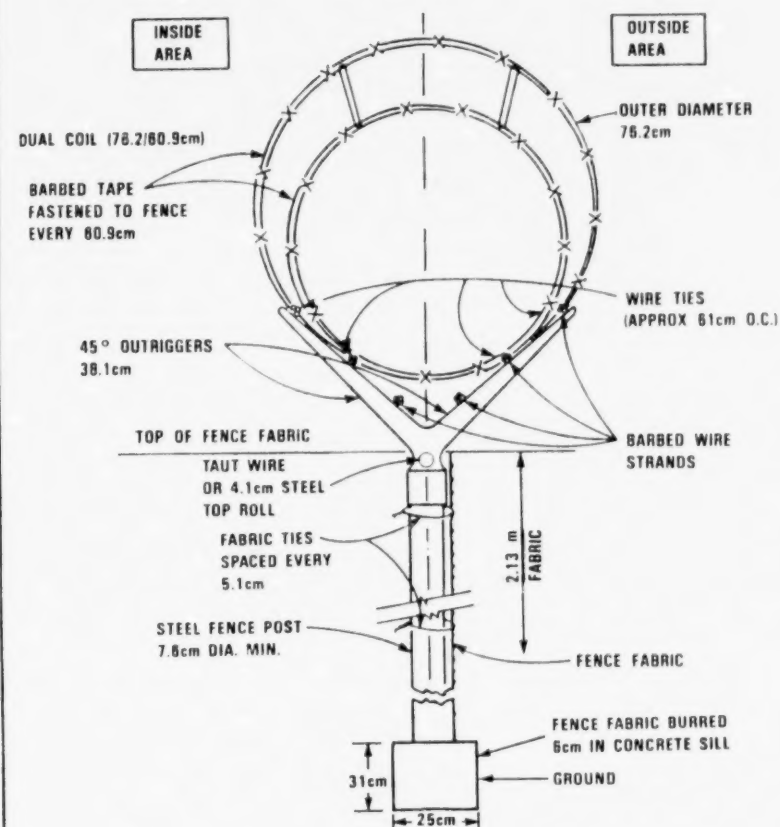
1. Perimeter fence, gate, and locks

Fence--All DCS sites shall be surrounded by a continuous perimeter fence as specified in the figure below. New fences shall extend no less than 2.1 meters from the ground to the top of the fence fabric. Existing fences that are at least 1.8 meters to the top of the fabric can be modified to the specifications here; otherwise, existing fences shall be replaced. The perimeter fence shall serve as a legal and physical demarcation of the restricted area boundary. It shall be no less than 9 meters from any facility or equipment critical to the operation of the DCS. Also, it shall be no less than 3 meters from trees, poles, buildings, or other potential climbing aids outside. The distance between the fence and outside trees, poles, buildings, or other potential climbing aids shall be greater than 9 meters. (9) 5.1.3.3.1



FENCE. (9) fig. 6

guidance SECURITY/2 Zone 1



FENCE - CROSS SECTION. (78) 140

guidance SECURITY/2 Zone 1

Although barriers can assume a wide range of forms, such as walls, ditches, berms, and barricades, the scope of security guidance provided in this section is limited to fences. The principal point to recognize about fences from a security viewpoint is the negligible penetration time they provide against a determined threat. The same point, of course, can be made about perimeter security walls. For penetration time information about such walls, see the discussion in SB7-"Security" that relates penetration times to attacks through reinforced concrete, concrete masonry units (CMU), and stone walls. To save time, an intruder will probably go over a wall rather than through it. For attacks that involve penetrations either over or under perimeter fences, the data provided in this section should be used. Care should be taken to use penetration time information that relates to the correct height of a perimeter barrier, whether it is a wall or a fence. As the information below demonstrates, fences should not be routinely specified for physical security delay purposes. (37) 13.1-126

Functions. Fences used for physical security serve multiple functions, including one or more of the following:

- Provide a legal boundary by defining the outermost limit of a facility.
- Assist in controlling and screening authorized entries into a secured area.
- Support detection, assessment, and other security functions.
- Deter "casual" intruders from penetrating a secured area.
- Cause an intruder to make an overt action that will demonstrate his or her intent.
- Briefly delay access to a secured area or to construction facilities adjacent to secured areas.

Selection factors. (37) 13.1-128 The facilities engineer should select the most cost-effective exterior fences, considering the penetration time requirements, cost constraints, and functional requirements.

In general, fences (conventional or hardened) offer less than 2 minutes of penetration time. However, they can be constructed of materials that give the appearance of hardness, which will deter the casual intruder but not the dedicated one.

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Cost must be considered from the viewpoint of fence configuration and maintenance. As pointed out above, fences do not offer much delay time but can be constructed to appear impregnable. This will affect cost considerations since the appearance of impregnability will necessitate new design configurations. Such configurations will probably necessitate the increased use of fencing material (such as barbed tape and fabrics) and, thus, increase cost. Added fence materials may also increase the cost of maintenance due to increased material replacement that results from the effects of inclement weather, unusual environmental conditions, animals, and pranksters. A double fence constructed of chain link with one of the fences topped with barbed tape, costs more than \$55 per foot (300 millimeters) of perimeter length.

Fences should be designed to complement the other physical security elements. The fences should not produce glare and should be built so that they will not prevent a guard or CCTV camera from looking into the zone beyond.

Evaluation of fence penetration times. (37) 13.1-128 Exterior fence configurations that have been tested to date offer very limited delay time. At present, the only fences that have received research, development, test, and evaluation are those made of standard metal fence fabric with various enhancements. At present, Naval physical security instructions recommend that

The degree of obstruction assured by a permanent physical barrier shall be comparable to that provided by a chain link fence, using No. 9 gage [3.8 mm] wire; with mesh opening not larger than 2 inches [50 mm] per side; 6 feet high [1,800 mm] (including an 18 inch [450 mm], 45 degree outrigger, facing outward, strung with three strands of No. 12 gage [2.7 mm] barbed wire, spaced 6 inches [150 mm] apart) (OPNAVINST 5510.45B, except as proposed for modification by OPNAVINST 5530.XX, May 1981).

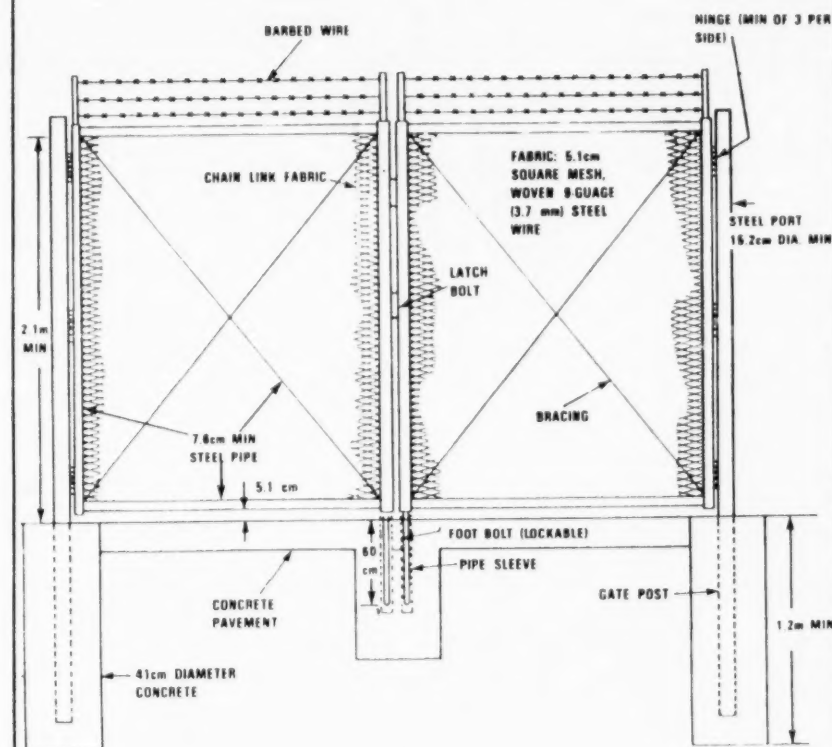
guidance SECURITY/2 Zone 1

This recommendation for a standard security fence is consistent with the penetration time information known for common chain link fences. Such fences provide penetration times of less than 2 minutes and therefore should not be deployed with the expectation that they will significantly delay dedicated intruders. The discussion below, relating to fence hardening options, demonstrates that enhancements do not alter this conclusion. Consequently, the security engineer who decides to expend greater resources on fencing configurations of the type described below should do so either because a military regulation requires it or because there is a specific determination that such a fencing configuration provides a greater increment of deterrence than the standard security fence. A variety of fence configurations has been tested to obtain baseline penetration times. Trained and dedicated intruder teams have demonstrated a consistent ability to quietly penetrate 8-foot (2400-millimeter) chain link fences topped with barbed tape within 3 to 8 seconds.

COMMON CHAIN LINK FENCE MATERIALS.

Component	Options
Gage	#9 (3.8 mm), #11 (3.0 mm).
Mesh	2 in (50 mm), 40mm, 60mm
Coating	Vinyl, galvanized
Tension wires	Wire, rail, cable (attached at top and/or bottom)
Support posts	Metal posts (see Federal Specifications RR-F-191H/GEN and RR-F-191/38)
Height	6 ft (1,800 mm), 7 ft (2,100 mm), 8 ft (2,400 mm).
Fabric tie downs	Buried, encased in concrete, staked
Pole reinforcement	Buried, encased in concrete
Gate opening	Swing, slide, lift, turnstile

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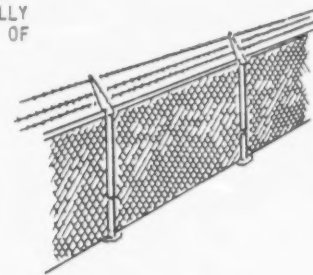
FENCE GATE. (78) 143

guidance SECURITY/2 Zone 1

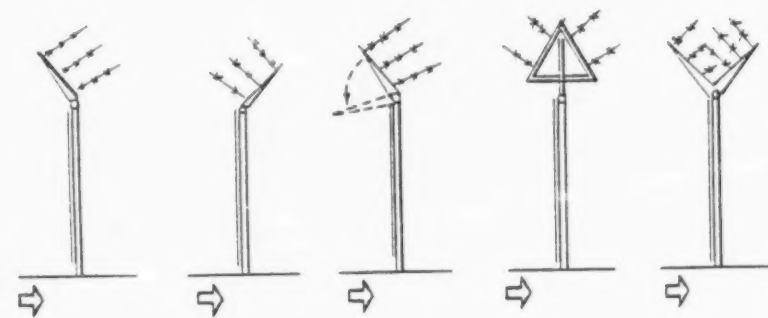
Hardening options. (37) 13.1-130 Since fences alone offer very little deterrence against dedicated intruders and even less penetration time, much attention has been given to the development and testing of enhanced fence configurations. Chain link enhancements are typically limited to different configurations and combinations of barbed wire outriggers, barbed tape concertina, and General Purpose Barbed Tape Obstacle (GPBTO, developed by the Navy). Figures below identify some enhanced fence configurations recently tested. As with conventional fences, the hardening options and enhancements available do not significantly affect penetration times (less than 2 minutes). Other measures to the standard fence, however, will improve its deterrent value, durability, and perhaps, its penetration time. The fence height has proven to add little more than seconds to the penetration time. To increase the difficulty of penetrations under a fence, it is recommended that some form of fabric tiedown be installed. Tiedowns vary in type from steel wires holding the fabric firmly to anchor posts, to encasing the fabric in a concrete sill. The use of tension wires along the lower portion of the fabric will also hamper, although certainly not stop, a penetration attempt.

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FENCE OF STANDARD CHAIN
LINK MESH, WITH ONE OR
MORE OUTRIGGERS, USUALLY
HOLDING THREE STRANDS OF
BARBED WIRE EACH



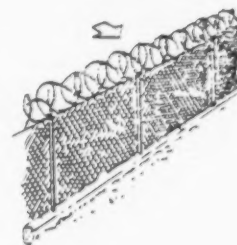
A. GENERAL DESCRIPTION



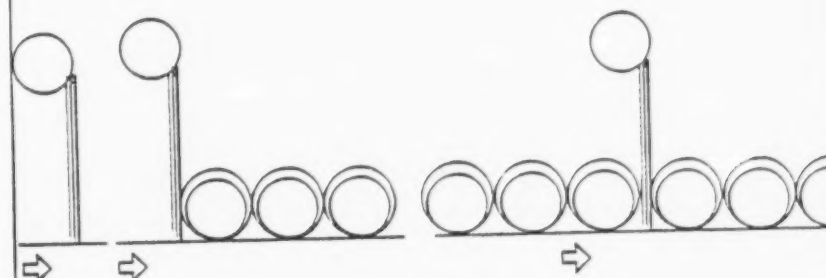
FABRIC WITH BARBED WIRE OUTRIGGERS FENCE CONFIGURATION. (37) 13.1-131

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FENCE OF STANDARD
CHAINLINK MESH,
WITH ONE OR MORE
COILS OF BARBED
TAPE ATTACHED
TO THE FENCE
AND/OR ADJACENT
TO THE FENCE



GENERAL DESCRIPTION

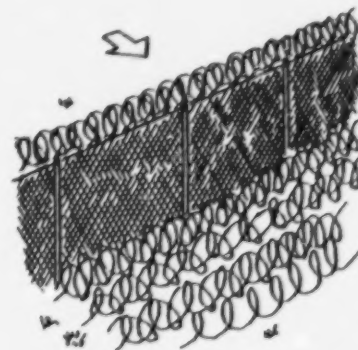


EXAMPLES

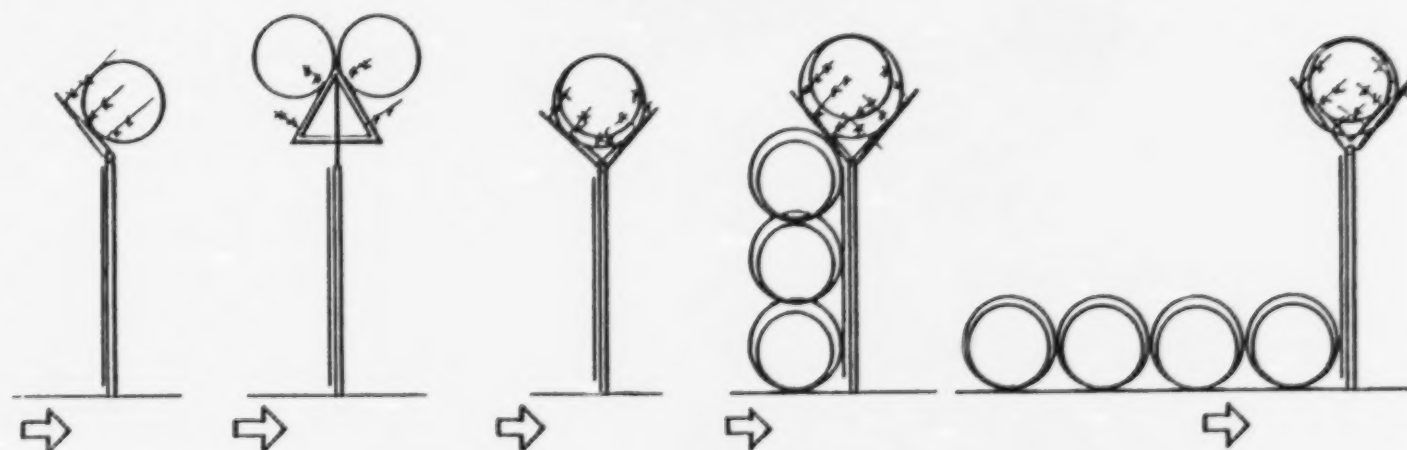
FABRIC WITH BARBED TAPE COILS FENCE CONFIGURATIONS. (37) 13.1-132

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FENCE OF STANDARD
CHAINLINK MESH,
WITH BARBED WIRE
OUTRIGGERS AND
BARBED TAPE COILS
AS DESCRIBED ABOVE



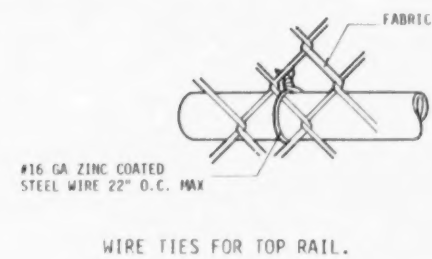
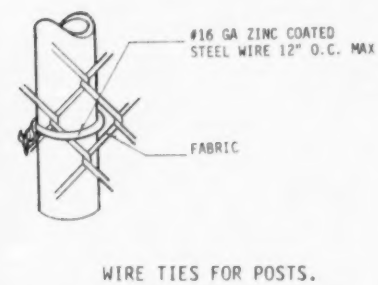
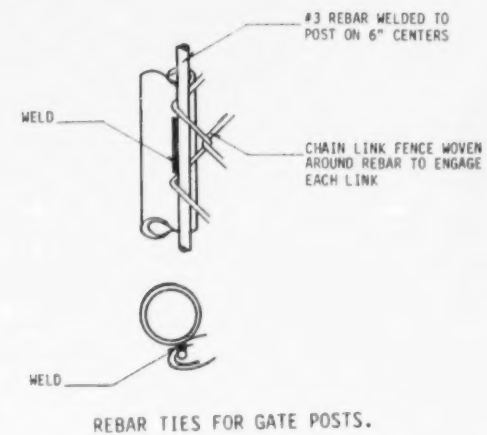
A. GENERAL DESCRIPTION



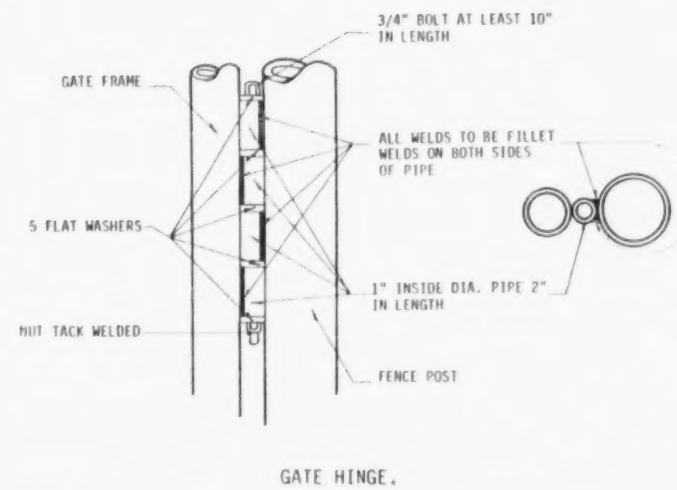
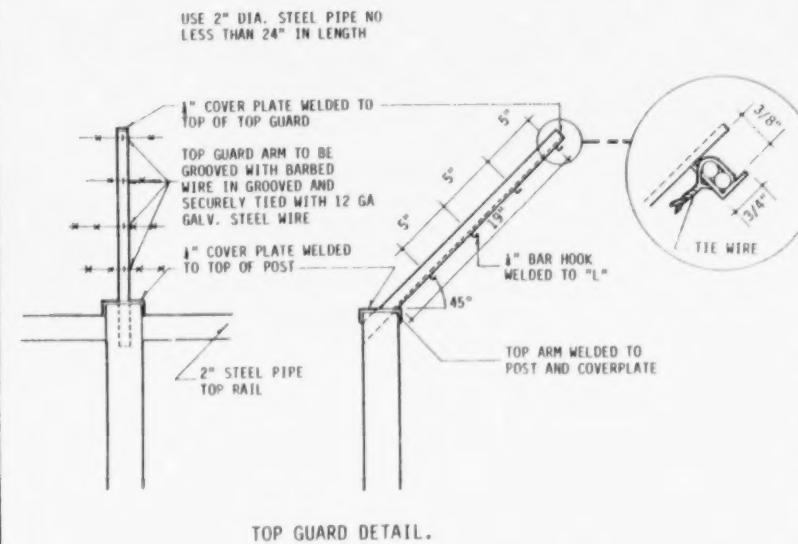
EXAMPLES

FABRIC WITH BARBED TAPE COILS AND BARBED WIRE OUTRIGGERS FENCE
CONFIGURATION. (37) 13.1-133

guidance SECURITY/2 Zone 1

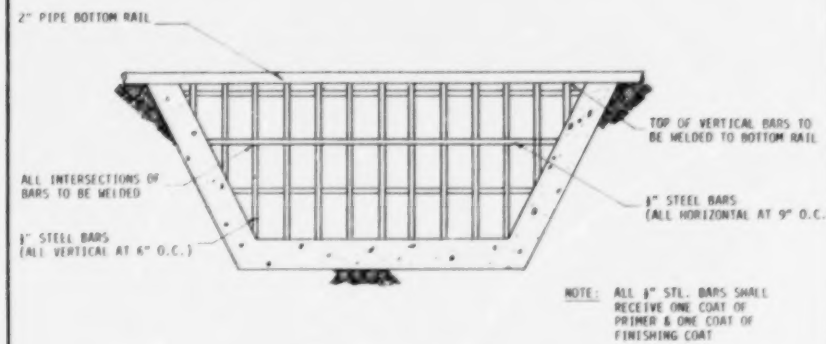


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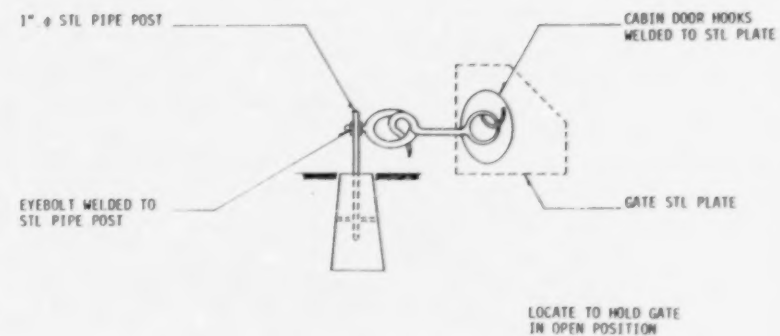


guidance SECURITY/2 Zone 1

Drainage. Drainage shall be provided to prevent standing water from accumulating near the perimeter fence. All drain lines or culverts extending through the fence lines with cross-sectional area greater than 624 square centimeters and a smallest dimension greater than 16 centimeters shall be protected by a welded steel grid or replaced by multiple pipes of 25 centimeters diameter or 619 square centimeter area or less. (9) 5.1.3.3.1.1

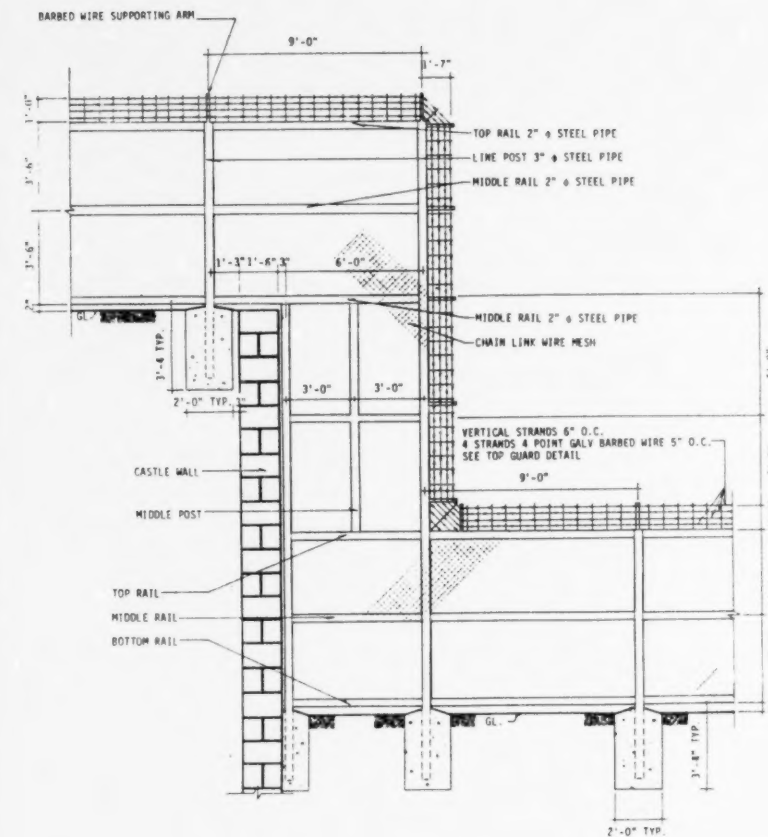


TYPICAL SECTION OF DRAINAGE CROSSING.



GATE LATCH DETAIL.

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FENCING DETAIL FOR GRADE CHANGES.

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Gates--The number of gates shall be kept to the minimum needed for efficient site operation. Only one entry point shall be established, and its location shall be based on logical routes of travel into the site. Entry gates shall be positioned parallel to service or main entry roads. When entry through a gate is adjacent to heavily traveled roads, the gate shall be offset a minimum of 6 meters from the edge of the road for vehicle safety. Gates not under security force observation shall be securable to the strength of the adjacent fence construction. Such gates shall be locked. (9) 5.1.3.3.1.3

Entrance. Vehicle and personnel gates shall be secured with high-security padlocks. At unmanned facilities, gates shall be locked at all times, even when maintenance personnel are on site. At manned facilities, gates shall be locked at all times except during times of heavy traffic through the gate (for example, shift changes), at which time an on-site guard shall be posted at the gate. (9) 5.1.3.3.1.4

Entry point lighting. Entry point lighting shall be used at manned facilities for which entry controls are required during normal operations. Entry point lighting shall facilitate accurate and rapid identification of personnel requiring entry into the site. Two or more light fixtures shall be placed such that the light sources are above and behind the entry controller and face the person approaching the site. The entry point lighting intensity shall be no less than 16 lux for a distance no less than 15 meters outward from the entry point. (9) 5.1.3.3.1.6

Site entry control. Site entry control procedures shall be established to help control entry and exit of personnel and vehicles for both manned and unmanned DCS facilities according to the guidelines presented below. Only authorized and essential personnel shall be allowed access to DCS sites. Authorization requirements shall be established according to the needs of the individual DCS site (for example, security clearances). Unauthorized individuals shall never be allowed access to a DCS site without continual escort by personnel empowered by the site commander to authorize the entry of those individuals. (9) 5.1.3.3.2

For an unmanned DCS site, entry shall be controlled by adopting a set of procedural guidelines with an overall objective of verifying the authority of each person seeking entry. These guidelines shall consist of step-by-step instructions to be carried out by personnel requiring access to the site. As a minimum, these guidelines shall include the following steps.

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a. Log books shall be established and maintained to record pertinent information about each site entry (for example, names of individuals, vehicle used, estimated and actual time in, time out, purpose of visit). Log books shall be kept at the facility charged with O&M of the unmanned DCS site and at the facility charged with dispatching a response force on sensor alarm. Log book entries shall be completed before and after each visit.

b. An estimated time of arrival on site shall be established for each visit and shall be adhered to as closely as possible. Alarms triggered by an authorized entry shall correlate with estimated time of arrival for logged site visits.

c. Upon access to a site, all gates shall be closed and locked.

d. Upon access, telephone contact shall be made with the facility charged with dispatching a response factor on sensor alarms and with the facility charged with O&M responsibility. A prearranged code word or signal shall be passed to insure personnel are not being held hostage.

e. Upon exit, telephone contact shall be made with the facility charged with dispatching a response force and with the facility charged with O&M responsibility. All gates shall be locked after passage. (9) 5.1.3.3.2.1

Entry into manned DCS sites shall be controlled by adopting a set of procedural guidelines with the overall objective of verifying the authority of each person seeking entry. These guidelines shall consist of step-by-step instructions for personnel and vehicle movement control. As a minimum, these guidelines shall include the following steps:

a. Access lists shall be established to identify personnel who have authorized and valid access rights commensurate with the security clearance requirements of the site. Access to a DCS site shall be limited to only those on the access list. Personnel not listed who have a valid need for site access shall be escorted at all times. On-site guards shall not be used for escort.

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b. A procedure shall be established for positive identification of persons with authorized access to the site. This procedure shall include security identification cards and badges. However, for small sites, personal recognition may be used.

c. If an on-site guard is posted at an entry gate, that guard shall make visual assessments of all personnel requesting entry to the site. The guard shall have a fixed or portable duress alarm available.

d. For sites where no 24-hour on-site guard is posted at an entry gate, a call box or intercom shall be maintained at the perimeter fence gate. A CCTV system shall be installed to allow remote assessment of personnel requesting access. A fixed duress alarm shall be positioned near the CCTV screen.

e. Only authorized and official vehicles shall be allowed on site. Personnel parking shall be maintained outside the perimeter fence. (9) 5.1.3.3.2.2

Emergency personnel for firefighting, medical assistance, or other situations shall be permitted entry to a site without delay. Said emergency personnel shall be kept under escort and surveillance by site operational or security personnel at all times and shall be restricted to the area containing the emergency situation. (9) 5.1.3.3.2.3

All gates, manholes, cable vaults, and doors shall be locked with high-security, key-operated padlocks that meet or exceed the requirements of MIL-P-43607E. Key control procedures shall be adopted that consist of step-by-step instructions to be carried out for issuing and maintaining keys. As a minimum, these instructions shall include the following steps:

a. A key control officer shall be appointed to have overall responsibility for issuance and maintenance of keys and locks.

b. Keys shall be accessible only to persons whose official duties require access. A record shall be kept of the total number of keys and the names of persons to whom keys have been issued.

c. Padlocks shall be changed on a regular basis and upon possible compromise of a key.

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d. Keys shall be stored in a locked container when not in use. Access lists for those authorized to draw keys shall be kept in the same container.

e. Keys shall not be issued for personal retention. (9) 5.1.3.3.5

2. Cleared area between perimeter and inner fence

An extended clear area at least 9 meters wide shall be maintained inside the perimeter fence by using chemicals or routine ground maintenance. The cleared area shall have no obstacles, topographical features, or vegetation greater than 20 centimeters high. (9) 5.1.3.3.4

3. Warning signs

Warning signs shall be posted at 30-meter intervals along the perimeter fence and on all gates. These signs shall be posted so that they do not obscure sizable portions of the perimeter fence and approaches to it. (9) 5.1.3.3.1.2

Restricted area signs shall be posted on all sites subject to the jurisdiction or administration of, or in the custody of, DOD or military departments of the DOD according to the requirements of DOD Directive 5200.8 and Section 21 of the Internal Security Act of 1950. Posted signs shall not reveal the nature of the site's operation and shall not present information about site personnel. Specific wording on signs shall be consistent with host national requirements and shall be posted in both English and local languages. (9) 5.1.3.3.3

Warning signs should be installed intermittently along the entire perimeter fence and at each entry point to be readily seen by anyone approaching the site. These signs should be placed so they do not aid intruder concealment or significantly obstruct the view from the site. In overseas areas, warning signs should be posted in English and the local language(s). Signs should clearly state the dangers of trespassing in restricted areas. Specific words used should be consistent with host nation requirements. The signs should be:

- At least 1 foot high by 2 feet wide
- Painted with reflective material, consistent with tonedown procedures
- Legible at a distance of 50 feet
- Positioned on the outer fence at no greater than 100-foot intervals unless passive camouflage techniques are being used.

guidance SECURITY/2 Zone 1**4. Sensors**

One or more intrusion sensors shall be installed within zone 1 for detecting unauthorized penetrations into manned and unmanned facilities. Sensors shall be installed inside the perimeter fence. For unmanned facilities, the sensor output shall trigger an audible alarm on site as well as in the facilities charged with alarm assessment and response force dispatch for that site. For these sites, the alarm shall not be deactivated at any time. At manned facilities, the sensor output shall trigger an audible alarm on site only. The alarm shall not be deactivated unless the perimeter fence gate is opened to accommodate heavy traffic. (9) 5.1.3.3.6

Based on the typical operating environment of manned and unmanned DCS sites, sensors applicable to zone 1 were ranked in terms of their applicability (see the table below). (9) 5.1.3.3.6.2

SENSORS APPLICABLE TO PERIMETER SECURITY^a

Ported coaxial cable (PCC)
Individual resource protection sensor (IRPS)
Magnetic intrusion line sensor (MILES)
Bistatic microwave
Point sensor (electromagnetic)
Electric field fence (EEF)
Laser fence sensor (IRCCD)
Infrared fence sensor (IRCCD)

^aTwo types of sensors at minimum are required to adequately assist perimeter security.

IDS system compatibility--The site intrusion detection system must be identified and included during the planning of site layout. Proper layout can increase both the effectiveness (high probability of correct detections) and efficiency (reduced false and nuisance alarms) of the IDS. Furthermore, IDS needs cannot be completely identified until the proposed site layout plan has been consulted. If the IDS is designed to provide surveillance of a long fence line, high system costs should be expected as a result of a relatively large number of false alarms and because of greater maintenance for a complex system. Detection and assessment sensors near the facility exterior are, in general, more effective from a performance and cost viewpoint. On the other hand, if the intrusion detection sensors and fences are close to the facility building, and if facility delay time is too low, the time available for effective security force response may also be too low. To insure that resources are wisely spent, the relationship between exterior sensor location, delay times, and security force response times must be examined carefully.

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Intrusion detection sensors--The following site characteristics should be evaluated to determine suitable sensors:

Site variations. These include soil conditions, pavement, ground freezing, streams, terrain, water lines, sewers, fence pole locations, buildings, and underground cables.

Environment. This includes temperature, wind, rain, snow, wildlife, thunder, lightning, earth vibrations, and vegetation.

Inherent component characteristics. These include sensor-to-sensor interactions, upkeep cost, stability, ability limitations, self-test, false alarm rate, probability of detection, cost, reliability, repeatability, and tamper resistance.

Man-made disturbances. These include underground telephone and power cables, generators, motors, power transformers, radio, television, radar, communications equipment, vehicle ignition, and auto, train, or aircraft vibrations.

Human engineering. Evaluate the ease of installation and maintenance, assessment, reporting, and personnel requirements.

Interfaces. These include hardware/hardware, hardware/human, sensor/junction, sensor/data transmission links, sensor/power source available, sensor/installation hardware, and sensor/tamper protection.

Documentation. This includes procurement, acceptance, installation, maintenance, software requirements, operational procedures, periodic checks, orderly checkout, and test plans.

Adversary attributes. Evaluate the threat level, tools, weapons, and methods of entry.

Clear zones--These serve to improve the ability of guards and the IDS system to observe the facility and to detect and assess intrusions. Clear zones are a useful element of a site layout, but are required only in special cases such as storage magazines. (37) 13.1-118

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Terrain--The exterior layout must account for site terrain features. If terrain is properly considered during the design phase, it can be used to enhance some security measures and, in rare cases, replace security measures. On the other hand, if the characteristics of site terrain are not dealt with, they can significantly limit the security system's effectiveness. In general, if not properly accounted for, terrain features may provide areas for intruders to hide in, may offer intruders protection from security force weapons, or may serve as assembly points for attacking forces.

Facility security considerations--The relationship between an individual building and the rest of the site, the additional security it derives from being part of a larger system, and its impact on the system's resources are discussed below. (37) 13.1-118

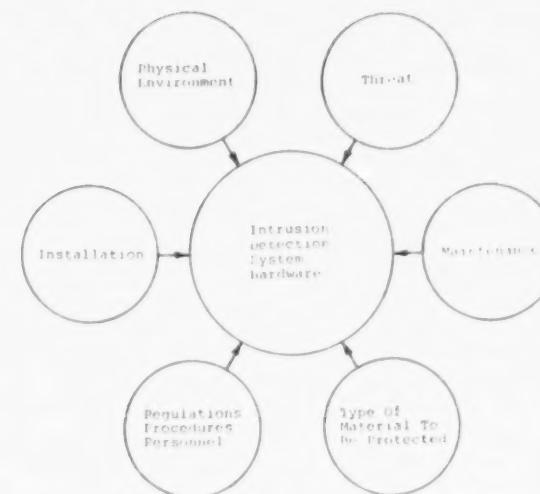
Location with respect to other buildings. It is important to consider a facility's location with respect to other buildings on the site. Specifically, nearby buildings should be identified in terms of both type and function. It may be possible, for example, for a tunnel to be dug from an unsecured building to the secured facility. High traffic areas should also be identified. Finally, the location of high-risk, protected areas should be noted as well as nearby firefighting, public safety, and security teams and equipment able to deal with emergencies.

Building orientation. If parts of the building exterior, especially the access points, are not observable from existing security posts or patrol routes, improved detection and assessment abilities as well as increased building delay time may be needed. This may require the use of IDS hardware, additional security posts, or patrol routes; in addition, it may require more frequent patrols. For building design before construction, it may simply involve reorienting the building.

Building location with respect to exterior barriers. The relationship between the facility and exterior barriers affects security. Consideration of barriers should not be limited to walls and fences, but should include natural terrain features, such as hill elevation and tree lines. In this way, potential penetration and ingress times beyond the facility's exterior walls can be identified. In the event a building is difficult to observe and is placed against a natural terrain feature, such as woodlands, additional security measures may be required.

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Determination of the facility intrusion detection system. The facility IDS design must be considered in conjunction with the site layout design. This is necessary to insure that layout and security equipment interface as efficiently and effectively as possible.



FACTORS THAT INFLUENCE INTRUSION DETECTION SYSTEM SELECTION.

Ported coaxial cable sensor--This is an exterior surveillance sensor designed to detect and locate intruders over long perimeters. It consists of an active electromagnetic sensor buried in the ground. The ported coax cable sensor is used optimally at large sites with perimeters up to 3200 K meters long. (9) 5.1.3.3.6.2

Operation. Ported coax consists of two identical "leaky" coaxial cables buried in the ground parallel to each other (see ground plan). A pulsed transmitter is

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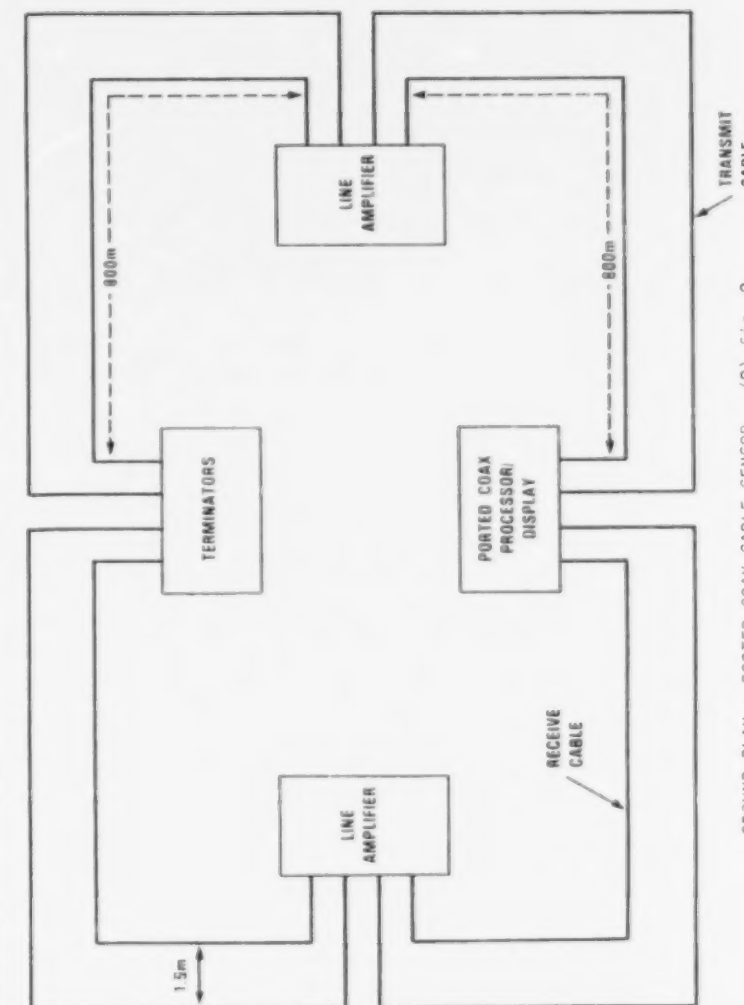
connected to one cable transducer and a receiver is connected to a second cable transducer. The operating frequency transmitted is in the 60-megahertz band (very high frequency (VHF)). Peak transmitted power is 800 megawatts. The pulsed energy causes a surface wave to propagate along the outside of the transmit cable. Part of this surface wave couples into the receiver cable, producing a VHF return signal at the receiver. When an intruder enters the electromagnetic field, this coupling between the transmit and receive cables is disturbed, which produces a change in the receive signal. Due to the nature of the short VHF pulse and the design of the ported cable, the intruder's location is determined by the time delay between the start of the transmitted pulse and the reception of the profile disturbance. This system will simultaneously detect and locate multiple intruders.

Installation. A site compatibility test is recommended before procurement and installation because performance characteristics are not yet established. The site compatibility test consists of installing a short pair of ported cables. The transmit signal is applied while received signal power is monitored for both normal and water-saturated soil. The test is done to determine if the system is compatible with the soil conditions at a given site.

Upon actual system installation, the tolerance on both depth and cable separation is not critical. Recommended installation parameters are presented in the figure entitled "Ported Coax Cable Sensor." Uniform installation is recommended to increase uniform system response. The burial surface should be graded to promote water drainage. With a separation of 1.5 meters, the vertical coverage of the sensor is expected to be approximately 3 meters.

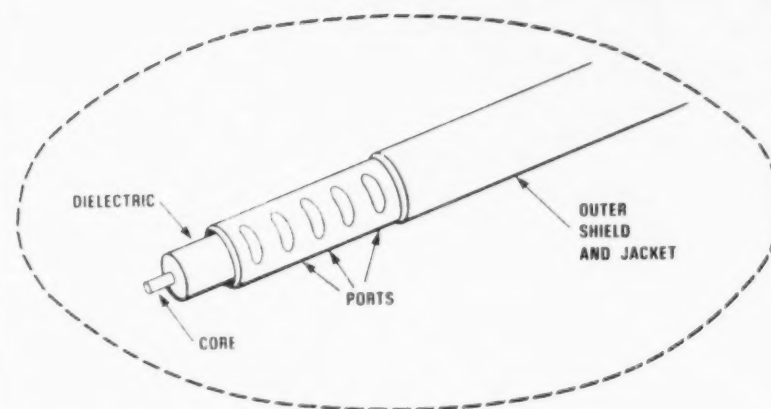
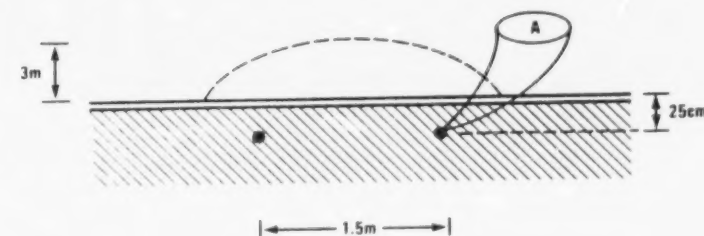
Maintenance. DOD guidelines shall be followed. A daily walk-through to test detection for each 100-meter section is recommended. The system contains a continuous self-test feature, including manual diagnostics and external test connections.

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GROUND PLAN - PORTED COAX CABLE SENSOR. (9) Fig. 9

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PORTED COAX CABLE SENSOR. (9) fig. 9

guidance SECURITY/2 Zone 1

Individual resource protection sensor (IRPS)--IRPS is a microprocessor-based, buried-line intrusion sensor for detection over short perimeter segments, up to 300 meters long.

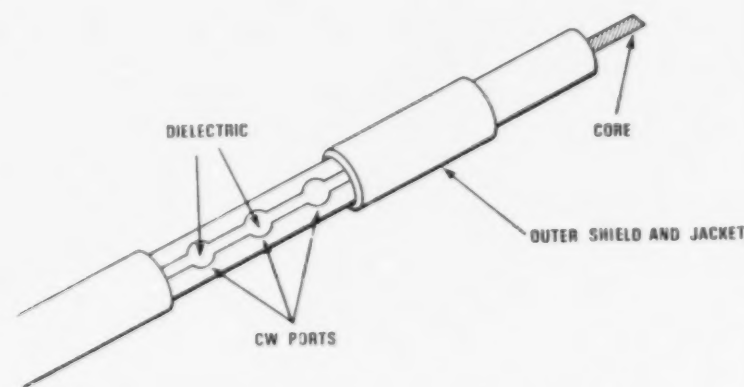
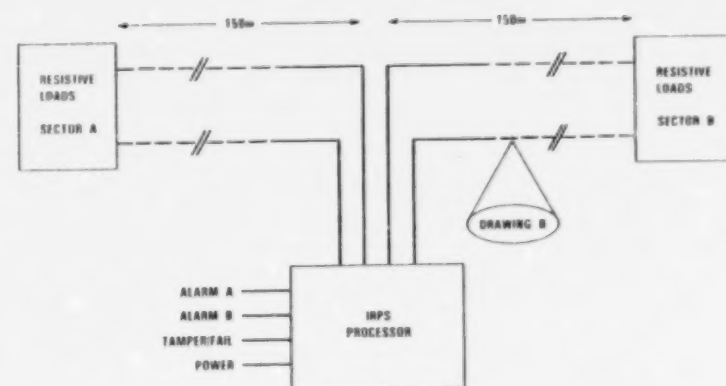
Operation. IRPS consists of two identical "leaky" coaxial cables buried in the ground parallel to each other (see the following figure). A transmitter is connected to one cable transducer and a receiver is connected to the second cable transducer. The transmitter cable is energized with a 60-megahertz CW signal that causes a surface wave to propagate along the outside of the transmit cable. Part of this surface wave couples into the receiver cable, producing a continuous return signal at the receiver. When an intruder enters this electromagnetic field, coupling between the transmit and receive cables is disrupted, which changes the receive signal. The IRPS system offers detection only, with no indication of the intruder's exact location along the 300-meter length of this cable.

Installation. A site compatibility test is recommended before procurement and installation because performance characteristics are not yet established. The site compatibility test consists of installing a short pair of ported cables. The transmit signal is applied while received signal power is monitored for both normal and water-saturated soil conditions. The test is done to determine if the system is compatible with soil conditions at each site.

Upon actual system installation, the tolerance on both depth and cable separation is not critical. A recommended burial depth is 25 centimeters, with a cable separation of approximately 1.5 meters. Uniform installation is recommended to increase uniform system response. The burial surface should be graded to promote water drainage.

Maintenance. DOD guidelines shall be followed. A daily walk-through to test detection for each 100-meter section is recommended. The system contains a continuous self-test feature, including manual diagnostics and external test connections.

guidance SECURITY/2 Zone 1



INDIVIDUAL RESOURCE PROTECTION SENSOR (IRPS). (9) Fig. 10

guidance SECURITY/2 Zone 1

MILES buried cable sensor--The Magnetic Intrusion Line Sensor (MILES) buried cable is sensitive to both magnetic and seismic disturbances and can sense crawling, walking, and running targets. The MILES sensor also can detect intrusions independent of the presence of ferromagnetic material. MILES is the sensory cable for the MAID/MILES sensor; MAID is the electronic processor.

Operation. MILES cable detection is based on the fact that motion disturbances will either move the cable in the earth's magnetic field or strain the cable's flexible magnetic core, thus changing the core's permeability. A disturbance will produce a signal in the sensing coil. If the response falls within a 4-hertz passband and exceeds a specified amplitude, an alarm is produced.

MILES is susceptible to false alarms from magnetic disturbances caused by lightning, power lines, buried power and signal cables and vehicle ignition noise. It is also susceptible to wind-induced ground motion and localized pressure sources such as moving vehicles, heavy equipment, and trains.

Installation. The MILES cable is installed in 100-meter segments. The sensor cable can follow irregular terrain. Multiple cables are overlapped as shown in the next figure. The depth of cable burial will differ with each site using the MILES sensor; therefore, it is necessary to perform an initial test installation at each site to determine the optimal depth. To determine the best depth, one 100-meter cable is cut to make as many as nine 10-meter lengths. It has been observed that the background noise will increase approximately in proportion to the square root of the length of the cable and that the sensitivity is independent of length. Using these facts in conjunction with the initial test installation, the best cable burial depth at a given site can be determined.

The cable is buried as shown. Installation is not recommended in asphalt or concrete unless the transducer's seismic ability can be ignored. The following table provides some specific guidelines for installing the MILES transducer near potential seismic sources.

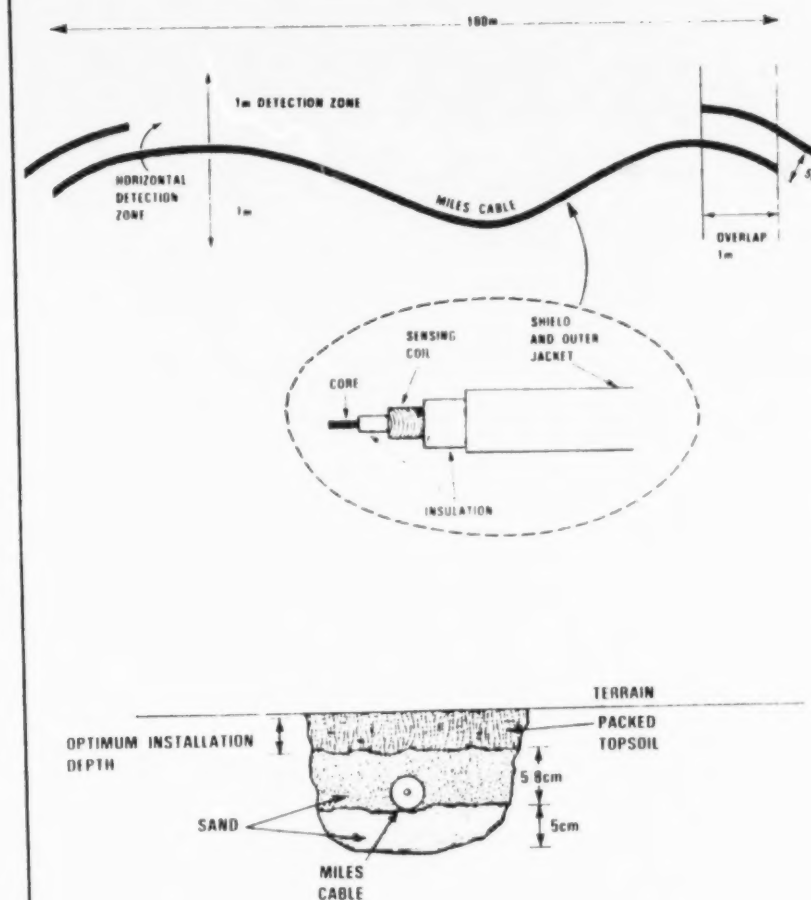
guidance SECURITY/2 Zone 1

GUIDELINES

Source	Recommended separation
Chain link fence	3 meters
Power poles	Equal to height of pole
Guy wires for power poles	6 meters
Tree drip lines	9 meters
Buildings housing machinery	6 meters
Roads with approx. 85 km/h traffic or heavy trucks	100 meters
Roads with approx. 16 km/h traffic and no heavy trucks	10 meters

Maintenance. The self-test feature of the MAID/MILES sensor shall be exercised at random intervals not to exceed 1 hour. Maintenance of the terrain, such as removing vegetation or filling eroded areas, shall be done as required. If the transducer is suspected of degraded performance, testing shall be initiated. Periodic performance testing is also recommended.

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MILES BURIED CABLE SENSOR. (9) fig. 11

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Bistatic microwave sensors--These sensors consist of an X-band source transmitting over a clear area of approximately 60 meters to a receiver. The transmitted signal is modulated at an audio frequency to form an amplitude-sensitive beam breaking system. Multiple sensors are required to cover large perimeters and corners (see figure below).

Operation. A bistatic microwave sensor is a line-of-sight device. The volume it encompasses is depicted in the second part of the next figure. The transmit antenna propagates a modulated signal toward the receive antenna. Terrain features, mounting height of the antennas, phase relationships, and other characteristics determine the received signal strength and the offset, which is the distance on the ground relative to the transmitter or receiver through which an intruder can crawl without detection. With an unauthorized entry into the detection zone, part of the transmitted energy will be deflected away from the receive antenna, which changes the signal strength and produces an alarm sequence.

The microwave sensor is susceptible to the crawling intruder and to tampering. In addition, the area between the transmitter and receiver must be kept clear of all obstructions, including grass or vegetation, to maintain a suitable false alarm rate.

Installation. Before installing a bistatic microwave sensor, the coverage area shall be prepared in the following way:

Grass and weeds shall be controlled by soil sterilization or surfacing.

Raised features shall be graded and depressions filled so that no site discontinuities over 3 centimeters in size exist.

The surface may be dirt, gravel, asphalt, concrete, or any combination as long as heavy rainfall will not erode the surface.

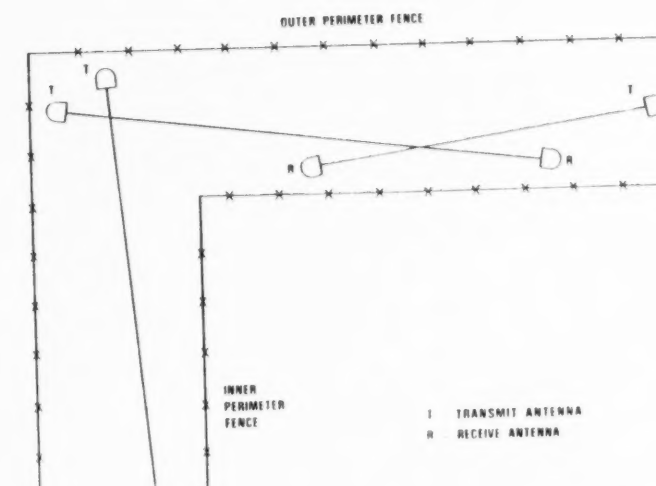
Structures such as towers, buildings, and fences shall be separated far enough from the microwave beam centerline to avoid reflections that would degrade the system's performance.

If deep snow is a problem at the site, snow fences shall be used.

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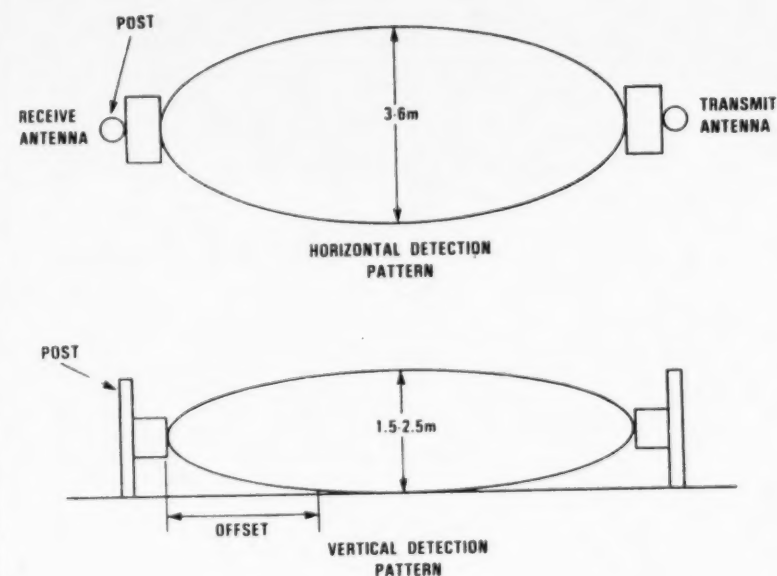
Installation of the sensor mounting post requires a fixed-location steel pipe embedded in concrete. The system requirements, such as the number of sensors to be mounted, will dictate pipe diameter and length. The pipe shall be installed as nearly vertical as possible. All exposed signal lines shall be enclosed in conduit. All connecting signal wires shall be run underground in conduit. Final elevation and azimuth alignment shall be done as recommended by the particular sensor manufacturer.

Maintenance. Periodic testing and maintenance is necessary to insure system reliability and performance. A regular, complete maintenance test shall be done every 6 months or when the system is suspected of performance degradation.



BISTATIC MICROWAVE SENSOR. (9) fig. 12

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BISTATIC MICROWAVE SENSOR, CONT'D.

CLIMATE AND WEATHER INFORMATION.

Weather Element	Type of information	Use or Significance of Information
Wind	1. Prevailing direction 2. Mean velocity 3. Peak gust velocity 4. Speed and direction distribution	If velocity is ≥ 47 km/hr, fence sensors may be activated. If velocity is ≥ 32 km/hr, wind-induced noise from trees, bushes, grass, buried posts, poles, and guy wires may cause seismic alarms. Ground pressure waves from strong winds may activate seismic sensors in clear environments. Wind-blown debris and subsequent pile-up on fences may cause false alarms and reduce visual assessment capability.

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Weather Element	Type of information	Use or Significance of Information
Temperature	1. Extreme minimum 2. Mean minimum 3. Mean maximum 4. Extreme maximum 5. Mean days/mo $> 38^{\circ}\text{C}$ or $< -18^{\circ}\text{C}$ 6. Frost depth	Equipment must operate under extremes of temperature. Seismic sensors may be desensitized if frost depth exceeds specified limits.
Rain	1. Mean total per year 2. Maximum in 24 hours 3. Rate and duration distribution	Indicates general soil moisture condition and variability. Excessive rain may dictate soil erosion control. Some seismic sensors are erratic in extremely wet soil. Periods of hard rain will increase seismic background noises. Assessment visibility will be reduced during hard rain.
Snow	1. Mean total per year 2. Maximum in 24 hours 3. Maximum accumulations 4. Drifting (depth, prevalence) 5. Rate and duration distribution 6. Water content	Increases amount of soil moisture. Decreases visibility if heavy; may require supplementary assessment measures. Snow depth > 15 cm may suggest use of snow control measures. Can decrease detection capability of some sensors if snow is of sufficient depth or has a hard surface crust.
Hail	1. Mean days of occurrence per year 2. Mean and maximum hailstone size 3. Mean and maximum accumulation 4. Rate and duration distribution	Hail produces seismic signals and false alarms from seismic sensors. Low, dense ground cover may attenuate the seismic. Large hailstones or prolonged occurrence may physically damage aboveground sensors. Like other forms of precipitation, hail decreases visibility and assessment capability.
Visibility	1. Mean days versus visibility range 2. Hours of day	Visibility reduction caused by rain, hail, snow, fog, dust, smoke, smog, etc, can seriously reduce assessment, depending on intensity and duration. Localized conditions can affect concentrations. Local observation may be warranted.
Airborne Corrosive Elements	1. Types of elements 2. Frequency of occurrence 3. Concentration in PPM	Protective coverings or coatings, or other measures may be warranted. Equipment must operate in this environment.
Electrical Storms	1. Mean days 2. Duration	Lightning can damage equipment. Signals.

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Sensor performance

Three performance characteristics associated with sensors are probability of detection (P_D), false alarm rate (FAR), and vulnerability to defeat.

Probability of defeat-- P_D indicates sensor performance in detecting an adversary within the zone covered. P_D involves not only the sensor's characteristics, but also the properties and environment of the site, the method of installation and adjustment, and the intruder's assumed behavior. For example, in addition to simply walking through an area, an intruder may attempt an intrusion by various methods such as running, crawling, jumping, or moving very slowly. Depending on the particular sensor, P_D may be considerably different for the different types of intrusions. The prevalent use of a single number to represent P_D of an individual sense or of an entire sensor system can produce misleading and erroneous results. If P_D is described by a single number, the conditions under which this number applies should be described also.

False alarm rate--FAR has been used to signify the expected rate of occurrence of alarms not attributable to adversary activity. For sensor evaluation per se, it is usually desirable to categorize nonadversary-related alarms as three types: false, nuisance, and unknown. Unless specifically stated, all three categories are included in the term "false alarm," i.e., false alarms are considered to be any alarms which are not caused by adversary activity. The false alarm rate (FAR) given as alarms per unit time, affects assessment activity since each time an alarm occurs, the assessment system must be employed. If there were no false alarms, the assessment system would be used only to determine adversary characteristics and direct response force actions. An acceptable FAR depends heavily on the ability to identify the source of each alarm. A high FAR will tend to undermine confidence in the system; for this reason, the system design goal should be to eliminate as many causes of false alarms as possible. The three classes of false alarms are described below.

False alarms. Alarms generated inside the sensor equipment. These may be generated by equipment failure, noisy connectors, electronic circuit defects, or other such malfunction. Proper procedure would be to replace or repair such faulty equipment. Experience has shown that, in properly operating equipment, FAR is of no consequence.

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Nuisance alarms. Alarms produced by sensors in response to a known stimulus unrelated to an intrusion attempt. Alarms generated by any known nonintruder stimulus would be classed as nuisance, even if the stimulus produced a sensor output identical to that of an intruder. For example, when persons, vehicles, or other authorized activity around a sensor results in alarms being generated, those alarms would be nuisances. Animals, wind, rain, EMI-caused alarms, and other such activity, also fall into the nuisance category.

Unknown alarms. Alarms for which the cause is unidentified. Reasonable efforts should be made to identify the cause of all alarms so that the number of unknown alarms is low.

Vulnerability to defeat--This is another measure of sensor quality. A sensor which is very good with respect to FAR and P_D would still not necessarily be a desirable choice if it is easy to defeat. Sensors can be made less vulnerable to defeat by equipping them with tamper alarms, anticapture circuitry, line supervision ability, and full end-to-end self-test ability. Installation practices such as overlapping the sensor fields to provide mutual protection for each sensor or the addition of special sensors (point sensors) to protect weak points in the sensor system are also essential considerations in the design of a sensor system.

Sensor choice

Typically, an IDS uses perimeter, building penetration, and interior motion sensors. Also, proximity sensors or movement sensors are often installed on critical or sensitive material. The sensors should not be considered separate entities since, together, they can provide a high P_D for the items being protected. This combination demonstrates a safeguard concept known as "protection-in-depth," which is simply several protective measures in series; that is, an intruder must successfully circumvent or defeat each protective measure in sequence before achieving access to the protected material or facility.

A major design goal is to obtain an IDS that has a low FAR and an acceptable P_D , and is not susceptible to defeat. This goal can be achieved by logically or hierarchically combining the outputs of different types of sensors. At present, no single sensor will reliably detect all intruders and still have acceptably low FARs in all natural and manmade environments. The number of sensor types in a system should not be increased or logically combined or implemented to decrease the system FAR without concern for the system P_D and vulnerability to defeat. Also, sensors should not be logically combined, implemented, or individually adjusted for high P_D with little regard for the concurrent increase in

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high P_D with little regard for the concurrent increase in sensor FAR under the premise that the overall system P_D must be as close to one as possible and the resulting FAR will be tolerated. This is acceptable only if the system FAR is equal to or less than the FAR that each security force will tolerate and at the same time still treat each alarm as a credible one. When this FAR is exceeded and the system is turned off or ignored, the system P_D rapidly approaches zone.

When using exterior sensors on the perimeter of an area or building, a well defined clear zone or isolation zone is highly desirable. Such a zone reduces FARs inadvertently caused by innocent people, large animals, blowing debris, and similar activity. Also, the perimeter should be divided into independently alarmed segments to localize the alarm's area. This provides for rapid assessment of an alarm and likewise can be used to assist response force operations. In addition, fences can move in the wind and cause false alarms; therefore, if fences are used to delineate the clear zone or isolation zone, they must be placed carefully.

ESTIMATES OF PROBABILITY OF DETECTION.

System Type	Electric-Field	Microwave	Infrared	Fence Motion	Taut-Wire	Seismic	Seismic/Magnetic	Ported Coax
Intruder								
Walking	VH	VH	VH	N/A	N/A	VH	VH	VH
Slow Walk	VH	H	VH	N/A	N/A	H	H	H
Running	VH	H	VH	N/A	N/A	H	H	VH
Crawling	H	M-H	M-H	N/A	N/A	M	M	VH
Rolling	VH	M-H	M-H	N/A	N/A	M	M	VH
Jumping	VH	M-H	H	VH	VH	M	M	H
Tunneling	VL	VL	VL	L	VL	L	L	M
Trenching	L	L-M	L	L	VL	M	M	VH
Bridging	L	L	VL	VL	VL	L	L	L
Cutting	N/A	N/A	N/A	M-H	H	N/A	N/A	N/A
Climbing	N/A	N/A	N/A	H	H	N/A	N/A	N/A

Key: VL - very low
L - low
M - medium
H - high
VH - very high
N/A - not applicable

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RELATIVE SUSCEPTIBILITY TO FALSE ALARMS.

Environment	Electric Field	Microwave	Infrared	Fence Motion	Taut-Wire	Seismic	Seismic/Magnetic	Ported Coax
<u>Weather</u>								
Wind < 47 km/hr	L	VL	VL	L	VL	L	L	VL
Wind 47 km/hr < WS < 115 km/hr	M	L	L	H	VL	M	M	VL
Wind > 115 km/hr	M	L-M	L-M	VH	L	H	H	VL
Rain	L-H	L	L	M	VL	L	L	M
Runoff, Standing Water	VL	M-H	L	L	VL	L	L	H
Snow	M	L-M	M	L	VL	L	L	L
Fog	VL	L	M	VL	VL	VL	VL	VL
<u>Animals</u>								
Small (Rabbits, Squirrels)	M	M-H	M	L	VL	L	L	VL
Large (Dogs, Deer)	VH	VH	VH	M	L	VH	VH	M
<u>Birds</u>								
Small	L	VL	L	L	VL	VL	VL	VL
Large	M	M	M	L	VL	VL	VL	VL
<u>Electrical Interference</u>								
Lightning - 1 mile	M	L-M	L	L	VL	L	H	M
Overhead Power Lines	VL	L	VL	VL	VL	L	M	VL
Buried Power Lines	VL	VL	VL	VL	VL	M	H	VL

Key: VL - very low
L - low
M - medium
H - high
VH - very high

guidance SECURITY/2 Zone 1**b. Deterrence and detection of intrusion**

Alarm assessment and procedures

An alarm triggered by a zone 1 sensor indicates the presence of one or more intruders inside the perimeter fence. The intruders' presence will be either authorized and, hence, predicted according to site entry procedures, or it will be unauthorized. For unmanned DCS facilities, the intrusion shall be assessed by two-way audio equipment, the output of which is carried on a voice-grade channel to the site charged with alarm assessment and response force dispatch. Once an intrusion is verified, the response force shall be dispatched and a verbal challenge offered over the audio assessment system. At manned facilities, prompt visual assessment shall be made using CCTV. Once an intrusion is verified, the response force shall be dispatched.

guidance SECURITY/3 Zone 2**3. a. Zone 2 security measures**

Security measures in zone 2 are installed to deter and detect intrusion to enhance alarm assessment, and to protect critical equipment against standoff weapons fire.

1. Inner fence area

Inner fence--All DCS sites shall be surrounded by a continuous inner fence located no less than 9 meters from the perimeter fence. The inner fence shall be located no less than 3 meters from trees, poles, buildings, or any other potential climbing aids inside that fence.

Drainage--Drainage shall be provided to prevent standing water from accumulating near the inner fence. All drain lines or culverts extending through the inner fence line with cross sectional area greater than 624 square centimeters and a smallest dimension greater than 16 centimeters shall be protected by securely fastened welded bar grills or replaced by multiple pipes of 24 centimeters diameter or 619 area or less.

Gates--Gates not under security force observation shall be securable to the strength of the adjacent fence construction and shall be locked.

Gatehouse--For sites that have a guard posted at the entry gate, a gatehouse shall be located within the inner fence and adjacent to its entry path.

Entry point lighting--Entry point lighting shall be provided as specified in "Zone 1 security measures."

Site entry control--Site entry for unmanned and manned DCS sites shall be controlled using the site entry control procedures specified in "Zone 1 security measures."

2. Sensors

Fence disturbance sensors (FDS) shall be required at manned sites and all essential unmanned sites. The FDS must be installed at the fence gate(s) and at intervals along entire perimeter. (11) III

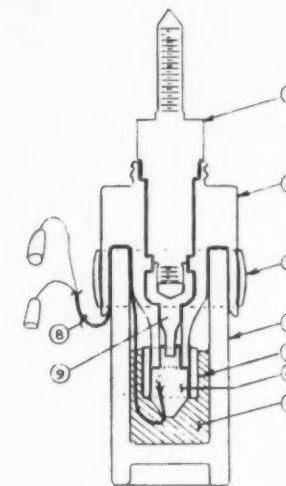
guidance SECURITY/3 Zone 2

The chainlink fences typically used to surround protected areas are somewhat flexible structures; thus, when an intruder attempts to climb over the fence, the fence moves. A climber generates two types of movement when climbing up the fabric: a slow, side-to-side movement of the chainlink fabric and a more impulsive, vertically oriented movement. If an attempt is made to cut the fabric, the cutting generates an impulsive shock which is transmitted through the fence fabric. This shock is generated by a combination of mechanical cutters shearing the wire and by the wires tension release when the fence fabric is cut. Fence movements that would be caused by other types of intrusions, for example, a climber cutting the fence with a torch, are similar to the types of movements described above. There is also a high-frequency noise generated when the fence fabric moves--a scratching caused by the rubbing of the fabric wires against each other. This noise would generally be caused by a climbing intruder or by wind moving loosely attached fabric. The fabric movements are coupled to the fence poles, so that if the fabric prevents the transmission of movement to poles, poor fence sensor performance results.

Four basic types of fence sensors generally detect different types of fence movement. These sensors are: mechanical, electromechanical, strain-sensitive cable, and taut-wire. The first three types are normally installed on an existing fence whereas the taut-wire sensor can be a free-standing fence.

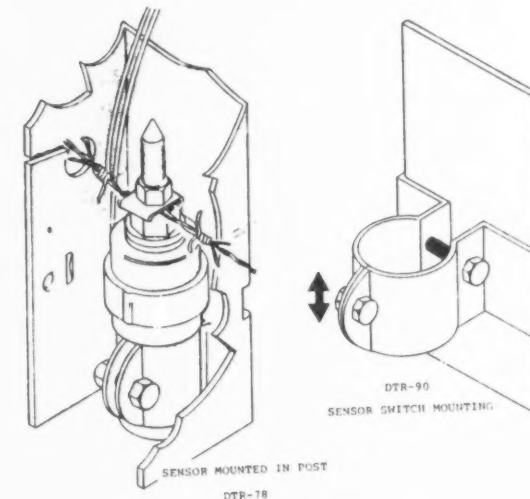
Install FDS or other suitable intrusion detection devices around entire perimeter fence at manned sites. Install intrusion detection devices on all essential facility entrances at unmanned sites. Due to the great stability of some fence posts at existing sites, some sensors (if FDS is used) may need to be placed on the fabric itself to enable actuation. However, most fence posts will move enough to actuate sensors placed on them; individual testing may be required in some instances. A compatible enunciator, with display unit and audible alarm, shall be installed in the site IMC. Use standard items whenever feasible to reduce logistics and maintenance problems. (11)

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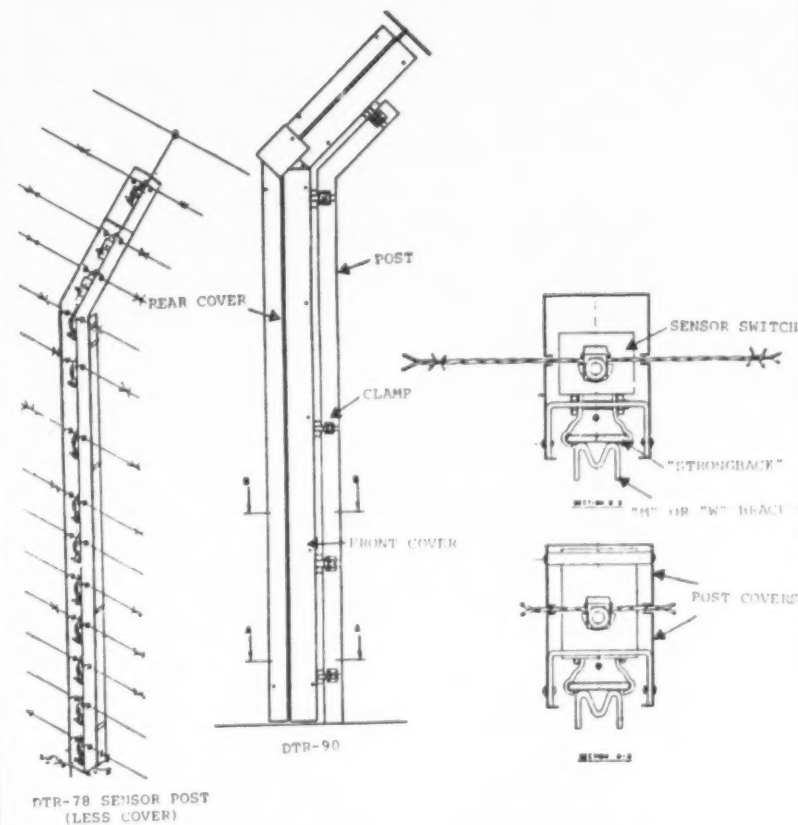
1. Cadmium-plated steel portion of lever-arm
2. Neoprene cap/plug
3. Metal band
4. Polycarbonate housing
5. Neoprene band, cylindrical
6. Cup-shaped Electrical Contact
7. "Plastic Putty"
8. Sensor switch "+" lead (soldered to contact cup)
9. Brass portion of lever-arm (with contact probe extending into the cup)

SENSOR SWITCH, CUTAWAY VIEW.



MOUNTING OF SENSOR SWITCH.

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3. Perimeter lighting

Standard exterior lighting--The type of lighting systems required depends on the overall security requirements of the base concerned. Four general types of lighting units are used for security lighting systems: continuous, standby, movable, and emergency. (37) 13.1-120

Continuous lighting (stationary luminaires). This is the most common security lighting system. It consists of a series of fixed luminaires arranged to flood a given area continuously with overlapping cones of light during darkness. The two primary uses of continuous lighting are glare projection and controlled lighting. (37) 13.1-120

Glare projection lighting uses luminaires slightly inside a security perimeter and directed outward. The glare projection lighting method is useful when the glare of lights directed across surrounding territory will neither annoy nor interfere with adjacent operations. It is considered a deterrent to a potential intruder because it makes it difficult to see inside the area being protected. It also protects the guards by keeping them in comparative darkness and enabling them to observe intruders at considerable distances beyond the perimeter. (37) 13.1-120

The controlled lighting method is best used when it is necessary to limit the width of the lighted strip outside the perimeter because of adjoining property or nearby highways, railroads, navigable waters, or airports. In controlled lighting, the width of the lighted strip can be controlled and adjusted to fit a particular need, such as illumination of a wide strip inside a fence and a narrow strip outside, or floodlighting a wall or roof. Unfortunately, this method of lighting often illuminates or silhouettes security personnel as they patrol their routes. (37) 13.1-121

Standby lighting. This type of system differs from continuous lighting in its intent is to create an impression of activity. The luminaires are not lighted continuously, but are either automatically or manually turned on randomly or when suspicious activity is detected or suspected by the security force or IDS. Lamps with short restrike times are essential if this technique is chosen. This technique may offer significant deterrent value while also offering economy in power consumption. (37) 13.1-121

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Movable lighting. This type of lighting system (stationary or portable) consists of manually operated movable searchlights that can be lighted during hours of darkness or only as needed. This system normally is used to supplement continuous or standby lighting. (37) 13.1-121

Emergency lighting. This system may duplicate any or all of the above systems. Its use is limited to times of power failure or other emergencies that render the normal system inoperative. It depends on an alternative power source, such as installed or portable generators or batteries. (37) 13.1-121

Lighting specification--The following table gives specifications for using proper amounts of light in visual surveillance at specific locations. This table provides general guidance for foot-candles as a function of location type. The next table, "Illuminated Area Specification," provides a guide for areas that should be illuminated. (37) 13.1-121

Lighting concepts--Exterior lighting can be designed for direct, indirect, intermittent, or responsive area illumination. (37) 13.1-121

LIGHTING SPECIFICATION (FOOT-CANDLES)
(37) 13.1-122

Waterfront boundaries	0.10
Entrances	2.00 (pedestrian) 1.00 (vehicular)
Industrial thoroughfares	0.15 (if not bordered by buildings) 0.40 (when bordered by buildings)
Open yards	0.15
Outdoor storage spaces	0.15
Piers and docks Land approaches	0.50 [horizontal out to 50 ft (15m)] 0.05 [vertical from 50-100 ft (15-30m)]
Decks of piers	1.00
Underneath piers	0.04
Critical structures	2.00

Source: United States Navy Physical Security Manual, OPNAVINST 5510.45B, Department of the Navy, Chief of Naval Operations 19 April 1971, except as proposed for modification by OPNAVINST 5530.XX, May 1981.

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ILLUMINATION AREA SPECIFICATION.
(37) 13.1-123

Type of Area	Width of Lighted Strip (ft, m)	
	Inside Boundary	Outside Boundary
Isolated fence boundaries	10 (3m)	25-200 (8-60m)
Semi-isolated fenced boundaries	10 (3m)	70 (21m)
Nonisolated fenced boundaries	20-30 (6-9m)	30-40 (9-12m)
Building face boundaries	N/A	50 (15m)
Unfenced boundaries	N/A	80 (24m) from building
Waterfront boundaries	10 (3m)	50 (15m)
Piers and docks (water approaches)		100 (30 m)
Piers and docks (land approaches)		Above as applicable

Source: United States Navy Physical Security Manual, OPNAVINST 5510.45B, Department of the Navy, Chief of Naval Operations, 19 April 1971, except as proposed for modification by OPNAVINST 5530.XX, May 1981.

Direct illumination. This lighting concept is the most widespread. It involves directing light downward from a roof to the ground immediately surrounding the structure. Its goal is to provide a specified intensity of illumination on intruders to facilitate their detection by CCTV or security patrols. (37) 13.1-124

Indirect illumination. An alternative lighting concept involves backlighting the intruders against the structure. This may be done by placing lighting away from the building and directing it back toward the walls so shadows will be cast on the building by the threat. This method is most effective if the luminaires themselves are near the ground level. This indirect concept is also aesthetically pleasing, as it illuminates the architecture during darkness. (37) 13.1-124

Intermittent lighting. A deterrent lighting system can be developed to turn lights on at random times. It

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can use either direct or indirect illumination concepts. Such a system can involve a duty cycle of 10 to 50 percent, although it may increase O&M costs by forcing the use of inefficient lamps or by reducing lamp life. Deterrence can actually be higher for such a system because it gives the appearance of activity. Luminaires can be controlled individually or as a group. (37) 13.1-124

Responsive area illumination. Rather than randomly activating the luminaires, an IDS sensor can be used to turn on the lights when an intruder is detected. This type of active lighting system provides maximum deterrent value at a low duty cycle. Such a responsive area system, if installed, is subjected to the same nuisance and false alarms of any sensor system. Since the lights will be activated more frequently than intruders will be present, the area should also be assessed using CCTV. (37) 13.1-124

Lighting for CCTV and surveillance

Lighting requirements for CCTV are considerably higher than those required for direct visual surveillance. CCTV cameras must be oriented so they are not blinded by the rising or setting sun and so the luminaires do not shine directly into their lenses. The optimal spectrum for CCTV lighting is different than that for human observation. (37) 13.1-125

Related lighting issues (37) 13.1-125

The interactions between a security lighting system and its contiguous, larger environment may be relevant to security lighting system design. These interactions involve the security lighting energy demand and its impact on certain legal issues, as well as the importance of restrike time as a performance parameter. Each interaction can place constraints on the lighting design and operation of the lighting system. These constraints, in turn, cannot be ignored when evaluating the impact of security lighting on crime. The energy, legal, and restrike issues are considered in more detail below. (37) 13.1-125

Energy issues--Since the energy shortage of 1973-74, virtually every system that consumes energy has come under scrutiny to identify possible energy savings, and security lighting systems are no exception. In fact, this scrutiny is probably as much related to the conspicuousness of security lighting as to the amount of energy consumed. The only statistics available on lighting pertain to the energy required to maintain street lighting systems, which constitutes a negligible amount, 0.18 percent, of the total energy consumed in the United States. Security lighting uses considerably less energy than street lighting. Recently, to reduce energy costs in security lighting, the security

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community has replaced luminaires with high-pressure sodium lamps to increase source efficacy. Sodium lamps produce more lumens per watt than either mercury vapor or incandescent lamps, which are the two most widely used lamps in the United States. The following table presents the relative efficacies and restrike times of alternative light sources. (37) 13.1-125

Legal issues. The law is becoming increasingly involved in two areas of street lighting in the civil sector. First, local building security ordinances have extended the concept of building codes to include property owners' obligations to take basic security-oriented steps, which include lighting. Second, the possible civil liability of individuals or municipalities for damages incurrent as a result of criminal activity following reductions in security lighting may create incentives for better illumination. Several cases have been reported for which a city or property owner has been found liable for negligence from the lack of adequate security and outdoor lighting. These types of liability problems may not apply to NAVFAC because of tortious immunity under the Federal Tort Claims Act. However, prudence may dictate security lighting as an element of the security system at or near facilities experiencing high loss rates. (37) 13.1-125

Restrike time. The differences in restrike time among the various lamps influence the selection of security lighting systems and concepts. For example, high-pressure sodium lamps are the primary light source of most security systems because of their efficacy (140 lumens per watt). However, these lamps have restrike times of 1 minute when cold and 7 minutes when hot. Fluorescent lamps are used as the emergency backup light source because of their short restrike time. However, they are not as efficient (77 lumens per watt). Therefore, the evaluation of any lighting concept such as intermittent lighting or responsive area illumination requires careful consideration of restrike times, lamp life, and energy requirements. The security engineer must decide if the short restrike timeline is economically feasible in relation to increased lamp replacement and energy costs. (37) 13.1-126

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RELATIVE EFFICACIES AND RESTRIKE TIMES OF LIGHT SOURCES
(37) 13.1-127

Lamp Type	Efficacy (Lumens/Watt)	Restrike Time (Minutes)
Theoretical maximum	683	-
Ideal white light	220	-
Incandescent	10 - 16	Fraction of a minute
Mercury vapor	30 - 65	3 - 7
Fluorescent	33 - 77	Fractions of a minute
Metal halide	75 - 125	Up to 15
High-pressure sodium	60 - 140	1 (cold) 7 (hot)
Low-pressure sodium	180	7 - 15

Source: J. E. Kaufman, ed., IES Lighting Handbook, Illuminating Engineering Society of North America, New York, 1981.

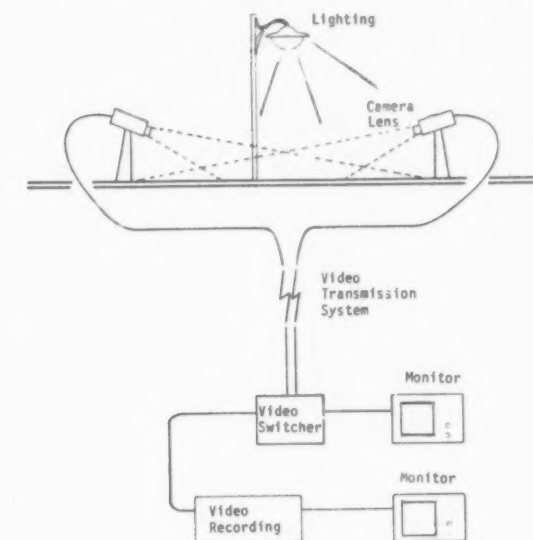
4. Closed-circuit television

Elements of a CCTV alarm assessment system--A video alarm assessment system provides security force personnel with a tool that, when used properly, permits rapid alarm display and evaluation from physically remote locations. In addition to real-time observation, a video alarm assessment system can record and store events. This permits subsequent replay of activity within the protected zone, even under conditions of multiple simultaneous alarms or delayed security personnel attention.

The video system consists of one or more cameras and lenses at the remote end, a display monitor at the local end, and various transmission, switching, and recording systems connecting cameras to display. The camera and lens convert the optical scene to a video signal, which is passed over a transmission system to a video switcher at the control location. The switcher can distribute the video signal to one of several monitors for display. A selected signal may also pass through a video recorder for delayed display or permanent retention.

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Auxiliary camera equipment is also available to better control the camera and lens system. System display or recording may depend on the form of sync generation. The output display can be augmented by adding alphanumeric data using information display equipment. Finally, the assessment system can be used as an intrusion detection sensor by installing a video motion detector.



BASIC CCTV ALARM ASSESSMENT SYSTEM.

Exterior protected zone layout--The shape and size of clear zones have a direct effect on the practicality and cost of a CCTV assessment system: (a) each bend in a fence may require another CCTV camera to provide area coverage (straight, clear, clear zones are desired); (b) clear zone width is one factor in determining CCTV camera lens choice, and thus, in indirectly determining lighting levels required, resolution possible (how small an object can you see), and cost of the lens.

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Additionally, the sensors should be laid out so that the CCTV assessment can cover the required area (indoors or outdoors) without placing unduly restrictive requirements on the assessment hardware (for example, difficult-to-obtain or unavailable lenses, improper field-of-view).

Before designing the CCTV assessment system, a decision must be made regarding the required resolution of the system. That is, is it enough to merely detect a man-sized object or will it be necessary to see small animals or identify an individual by recognizing the uniform or face? This decision is critical in specifying the number and type of cameras, camera placement, and quality of hardware to be used.

The minimum time allowed for assessment must be determined early in the system design so that the final system will insure adequate assessment of sensor alarms. For example, if security system operators have a number of responsibilities, it may take 3 to 5 seconds for attention to be focused onto a CCTV monitor to assess an incoming alarm. If the camera field of view is such that an intruder could pass from the sensors, through any barriers (fences), and out of the field of view in less than 5 seconds, instant video recording will be necessary to preserve the view of the alarm scene while the intruder is in it. Someone trained in CCTV system design should be consulted in choosing assessment equipment. The basic CCTV hardware can be more complex than sensor electronics and could compare in complexity to advanced display hardware. A CCTV assessment system can be almost entirely made of off-the-shelf commercial hardware. This makes system design straightforward, but the diversity of hardware types, abilities, manufacturer support, and other factors prevents simple implementation.

The CCTV assessment system must be able to provide information on multiple alarms.

Lighting is a major problem. Ideally, a scene should have uniform illumination at a level high enough to allow good CCTV resolution. No light sources, such as glare producing objects and reflective surfaces, should be in view—a goal which is highly desired but seldom achievable. A period of time after installation must be devoted to adjusting or moving lights, providing glare reducing screens, shielding lights, and similar matters.

The CCTV market is extremely dynamic, with an abundance of manufacturers and a wide variety of equipment. Care must be exercised during specification and procurement to buy well designed equipment that will be supported by the manufacturer. Modified equipment and unstable vendors should be avoided.

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System resolution requirements are determined by decisions about what should be seen. Implementing the system is then a matter of camera placement (geometric resolution) and equipment specification (hardware resolution). Since hardware can be procured with resolution ranging from less than commercial television specifications to several times commercial television, trade-offs can be made between geometric resolution (more or fewer cameras) and hardware resolution (more or less expensive equipment).

The CCTV assessment system requires maintenance. This must be anticipated during system specification so that equipment manuals are available, personnel are trained, and the system layout is maintainable (for example, cameras must be mounted so they can be accessed).

The system should be designed for expansion. As an example, video motion detectors or special recording abilities often require master synchronization for all cameras. If wiring for master synchronization is installed along with video cable, future installation of motion detectors is considerably simplified at less total cost than separately installing a video cable and a synchronization cable.

Some form of line supervision and tamper indication is necessary. This may be as simple as detecting whether a video signal is present or as complex as active supervision on data lines. Location, accessibility, and vulnerability of hardware will determine the level required.

Backup power is necessary for the equipment and for illumination. Emergency generators perform well enough for most video equipment and for incandescent lighting, however, most metal vapor lamps (for example, mercury vapor, and high-pressure sodium) will not relight immediately after a power outage. They may take up to 15 minutes to return to full brightness. These lamps are, however, much more efficient than incandescent lamps, so a careful trade-off, must be made between procedures for power-out operations, cost of lamps, cost of power, and UPS versus generator backup.

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Video signals are comparable to any other signals in their requirements for tamper resistance (line security), noise pickup (crosstalk, etc.) and lightning protection. Video signal cables are often installed at the same time and in the same place as sensor communication cables. The total system of cables must be designed such that cable combinations do not increase any of the above cited problems. Exterior cameras are often mounted on poles, interior cameras on brackets or pedestals. Mounting details must prevent interactions with sensors. For example, poles mounted near a buried cable can transfer wind-generated vibrations into seismic energy great enough to cause a buried cable alarm. A guideline is to use one pole length separation between the sensor and pole to preclude this. This separation may affect camera mounting height, field of view, and other parameters. The same effects can occur in interior installations from lens motion generating acoustic energy and ventilation-induced vibration.

5. Communication cables

To the extent practicable, consideration should be given to hardening both internal and external communications lines so that security forces will not be easily deprived of their use during emergencies. As already mentioned, communication lines essential to IDS alarm assessment must be hardened and protected with fail-safe features. Phone jacks for security personnel should be provided as necessary outdoors. Another possible option is to equip security personnel with handheld radios. (37) 17.1-119

All cables within zone 2 shall be buried.

6. Fuel storage

Protection--Fuel storage tanks shall be buried when possible. If these tanks cannot be buried, they shall be covered with a minimum of .5 meters of overburden. (9) 5.1.3.4.5

7. Fuel lines**8. Air-conditioning****guidance SECURITY/3 Zone 2****b. Intrusion detection and improved alarm assessment**

Alarm assessment procedures shall be used to verify a sensed intrusion. Specific procedures shall be adopted for dispatching a suitable response force when assessment indicates the presence of an intruder. (9) 5.1.3.4.3

Unmanned sites

Alarms at unmanned DCS sites shall be assessed by applying coincidence techniques to the sensors in zones 1 and 2. An intrusion is verified when sensors in zones 1 and 2 indicate an alarm condition within a time interval determined by the sensors' locations. When this condition exists, a response force shall be dispatched to the site immediately. When a single sensor indicates an alarm condition, the equipment building and tower shall be monitored acoustically in real time for 15 minutes to insure that an intruder has not penetrated the other sensor line(s) without causing an alarm. If acoustic monitoring indicates an attempt or actual intrusion, a response force shall be dispatched immediately. (9) 5.1.3.4.3.1

Manned sites

Alarms at manned DCS sites shall be assessed visually through the use of video cameras, a manned guard tower, or a suitable combination. Every sensor alarm shall be followed immediately by visual inspection of the area in which the alarm was triggered. A visually confirmed intrusion shall be followed by immediate deployment of the on-site guard force and dispatch of the off-site response force. (9) 5.1.3.4.3.2

On-site guard force procedures--When guards are on site, specific procedures shall be implemented detailing on-site guard force responsibilities for alarm assessment, initial alarm response, perimeter patrol, security measure inspection and assessment, entry control, key and lock control, and weapons control. (9) 5.1.3.4.9

Assessment--Upon activation of a perimeter sensor, guards posted in a guard tower or at a CCTV monitor station shall make a visual assessment. A verified intrusion shall result in immediate notification of the proper response force and immediate sounding of the DCS site's intrusion alarms. The guards shall then assume firing positions for initial response and defense of the site. (9) 5.1.3.4.9.1

Patrol--Guards shall conduct two-man patrols at random intervals to provide an intrusion deterrent and to inspect security measures such as fences, locks, doors, and lights for degradation. Their route shall be varied between patrols. Vehicular patrols may be used on large DCS sites; however, a foot patrol shall be conducted at least once daily to inspect the perimeter and inner fences. Patrols shall be armed and

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carry two-way radios to periodically communicate with site personnel. Night patrols shall avoid areas in which they are highlighted by site lighting. (9) 5.1.3.4.9.2

Entry control--Site entry at manned DCS sites shall be controlled by a guard posted at a gatehouse or at a CCTV monitor. (9) 5.1.3.4.9.3

C. Alarm reporting systems

Alarm reporting systems include a wide variety of equipment used for communicating alarm information from intrusion detection sensors to security personnel. In general, alarm reporting systems must be considered from both a hardware/engineering viewpoint (alarm transmission techniques and line security considerations) and a system procedures/human factors standpoint (display and console equipment abilities, features, and layouts).

Alarm communication systems

An essential part of an IDS is the alarm communication system, which transmits information from the sensors to the alarm display equipment. Two principal considerations of alarm communication systems are (a) the basic economic and technical aspects of the technique used to transmit the alarm information, and (b) the degree of security provided for the communication link. Several fundamentally different approaches can be taken to both alarm transmission and communication security. The advantages and limitations of each should be well understood so that the best technique for a given installation can be selected.

A wide variety of systems is available for presenting security information to security personnel, including:

- Annunciator panels that provide individual lights to display the status of every alarm circuit simultaneously
- Numeric readouts that use a single digital display to report alarm information from one alarm circuit at a time
- Computer-driven cathode ray tube (CRT) display that can present a variety of information about several alarm circuits simultaneously.

These approaches to alarm display offer a wide range of capabilities but also present distinct limitations and disadvantages. However, in selecting a particular alarm display system for a specific installation, it is essential that the features and capabilities required for the intended application be well understood. In particular, there is no one "best" system for transmission and display of security information. Rather, a system should be selected to meet the needs of the specific installation. It should also be noted that many systems may provide more capability than is needed or desired and that paying

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for unused features would tend to increase the system's cost.

Techniques available for transmitting alarm signals include land lines, radio links, dedicated point-to-point circuits, and shared multiplexed circuits. Each technique offers unique cost and performance advantages and each is usually best suited to a specific set of conditions.

In addition to the economical and technical aspects of the alarm transmission method, security must be considered for preventing or detecting improper reporting of alarm information due to accidental damage or malevolent attacks to the communications system. Two general approaches to secure communications are physical protection and supervisory techniques. Physical protection includes practices such as installing the communication line within the secure area, enclosing the line in conduit, burying the line (often in concrete), installing tamper sensors, and routinely patrolling the cable route. Supervisory techniques are characterized by some type of signal being continually transmitted along the communication link; this signal is constantly monitored to determine if the system is operating correctly and if the data have been altered during transmission. Regardless of the line supervision system used, such a system can almost certainly be defeated if the adversary is allowed access to the line for enough time and if the adversary has adequate resources and technical expertise; therefore, the line must be additionally protected by physical techniques to allow detection of attempts to gain access to the line.

Compatibility with operational procedures

The alarm reporting system should be compatible with security procedures and regulations. Although regulations are externally mandated to ensure that maximum security requirements are met, procedures are usually established by the installation. The role of procedures should be to state formally the rules to be followed and responsibilities of security personnel required to realize an efficient and effective security system. Among the reasons for adopting or continuing procedures are:

- A procedure may be needed to satisfy a regulation
- A procedure may be needed to address a specific problem which is site-dependent
- A procedure may be instituted because of the alarm reporting equipment (e.g., a Premises Control Unit that requires a guard to reset an alarm)
- A procedure exists because "it has always been done this way."

The first two reasons are valid, but the last two are

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questionable. Procedures should be reviewed periodically to evaluate their relevance. Acquisition of an alarm reporting system provides a good opportunity for this review. It is essential to determine how the proposed equipment will affect the existing procedures, that is, which procedures can be eliminated and what new ones will have to be instituted. Only then will it be possible to assess realistically the overall impact of a new or different alarm reporting system on security and guard operations.

An example of this point is the Premises Control Unit (PCU). If a PCU is included in an alarm reporting system, it is necessary to have someone at the remote site to set the zone to access or secure mode and/or to reset alarms. This may increase security by ensuring that someone visits an alarm site; however, it also requires additional manpower. It is possible to obtain systems that do not use a PCU and suffer no degradation of security. A guard could still visit the alarm location and report back without having to reset the alarm in the field. The inclusion of a PCU in a system should be based on a thorough analysis of the security needs, manpower, and other considerations; it should not be used simply because it is part of a vendor's "standard" system.

Another example of the important interplay between equipment and procedures is illustrated by tamper detection/line fault capabilities. If indications of these problems are ignored routinely, the additional equipment required to provide these capabilities is essentially wasted. On the other hand, if "trouble reports" are prepared for maintenance personnel as a result of these indications, true hardware problems will eventually be corrected and some instances of malevolent tampering may be discovered after the fact. However, the full benefit of these capabilities will only be realized by a response procedure requiring that the system be inspected whenever the indication is received, thus increasing the likelihood of apprehending an intruder.

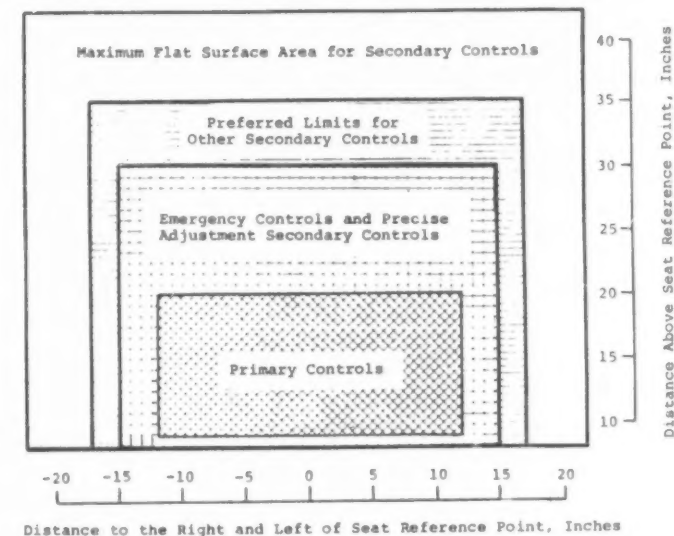
The amount of flexibility and responsibility an operator is given depends on installation needs, equipment, and management philosophy. A particularly significant factor is the composition of the guard/operator force: Are they provided by a security service (long term/short term)? Do they rotate through various stations or are they permanent specialized operators who have the same daily responsibilities? Is the level of training and responsibilities of guard/operators commensurate with the system being considered?

Human factors

No matter how sophisticated the system is internally, its external features should be engineered for the human operator. The guard/operator generally will have tasks to perform in addition to monitoring the display panel. The work area should be designed to coordinate these functions. The space available

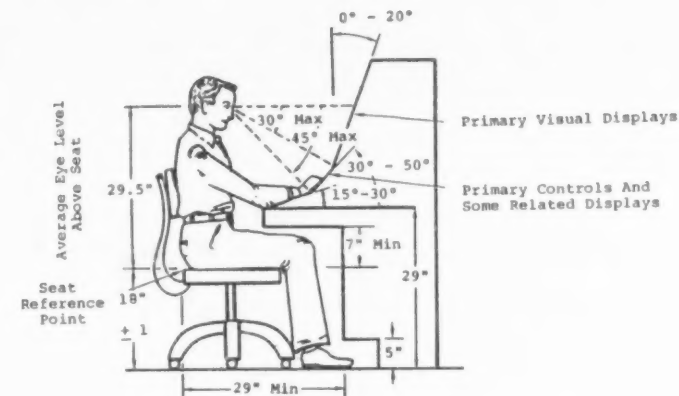
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around the operator would contain areas of varying accessibility and visibility. The figure below indicates how the space can be divided into different control areas. The main operating controls should be located in the primary area, with lesser used controls located in secondary areas.



PREFERRED VERTICAL SURFACE CONTROL AREAS.

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SAMPLE CONSOLE WITH PRIMARY VISUAL AND CONTROL AREAS.

Communications equipment such as microphones and telephones should also be integrated into the system. They should be within reach, operable with at most one hand, and have within long enough cords to allow the operator any necessary mobility. CCTV monitors and controls, if present, must be incorporated into the console design with the display and control space suitable for their intended function. The location of any auxiliary equipment should be in relationship to its importance and frequency of use.

Because the operator's attention may not always be directed to the display panel, there must be a way to attract his or her attention whenever it is required. Auditory stimuli could be used to alert the operator to a change of status and to indicate the general nature of the problem (e.g., fire, intrusion, explosion). Variable frequency sounds, such as sirens, are more alerting than steady-state sounds. Once the operator's attention is directed toward the display, a visual signal (e.g., a flashing light) can accentuate the important information. Colored lights or indicators can be used to indicate more clearly the alarms' status.

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The operator's work environment can vary between the extremes of boredom and exhaustion, depending on the workload. The workload should be composed of prioritized tasks, ensuring that the most urgent tasks are performed as soon as possible. Unrealistically heavy workloads that could lead to stress and fatigue should also be avoided.

If more than one operator is to be active at one time, it may be desirable to have a duplication of the essential display and communications equipment.

What information should be displayed

Although security can be maintained with a system that simply reports whether a zone is alarming, many display systems can present other types of information as well. Examples include:

- Access/secure alarm status of the zone
- Geographic location of the zone
- Time of alarm
- Supplementary text providing additional information such as special hazards or material associated with a zone
- Instructions describing special actions to be taken
- Telephone numbers of persons to call in emergencies
- Graphs or maps of the secure area.

Much of this information cannot be presented on annunciator or numeric displays. If a CRT display is used, the information displayed is subject to the CRT's limitations, such as the number of characters that can be written on each line and the number of lines that can be written on the screen.

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4. a. Zone 3 security measures

Security measures are installed in zone 3 for intrusion delay. (9) 5.1.3.5

1. Outer barriers (walls)

Critical buildings--All essential equipment and power sources shall be housed in buildings. Existing sites shall use in-place structures to the maximum extent possible. Unmanned sites that use trailers, vans or portable vaults to shelter essential equipment and power sources shall contain these shelters in vaults. (9) 5.1.3.5.1

Building entry control--Entry control into buildings on DCS sites shall be in accordance with specifications as described in "Zone 1 security measures." Entry control procedures for access into buildings or manned DCS site shall include the following guidelines:

- a. All doors shall be kept locked.
- b. Upon entering the site, authorized personnel shall be issued, the proper door keys and weapons storage keys by the key control officer.
- c. Upon leaving the site, personnel shall surrender those keys to the key control officer. (9) 5.1.3.5.3

Obscurants--All critical buildings and tower vaults on unmanned DCS sites shall contain smoke generators. These generators shall be activated by remote control from the facility charged with sensor monitoring, alarm assessment, and dispatching the response force. The smoke generators shall be equipped with a fail-safe mechanism to prevent activation when authorized personnel are in the building. (9) 5.1.3.5.3

Tower barriers--All antenna towers and free standing antennas on unmanned DCS sites shall be contained in vaults. At manned DCS sites, a fence shall be built around antenna tower bases and free standing antennas. (9) 5.1.3.5.2

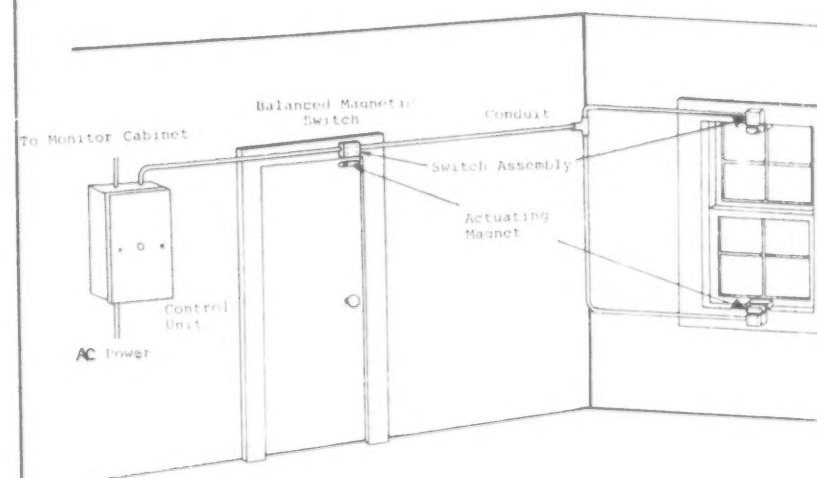
Guy wire protection--All guy wires and anchor points shall be protected by sleeves and vaults. All anchor points outside the inner fence shall be treated as separate, unmanned facilities and suitable security measures shall be applied. (9) 5.1.3.5.10

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2. Area between outer and inner barriers

Sensors--All doors at unmanned DCS sites and the doors to weapons storage lockers at manned facilities shall be equipped with balanced magnetic switch sensors. All critical buildings and tower vaults at unmanned DCS sites shall be equipped with interior microphones. (9) 5.1.3.5.6

Alarm assessment procedures--Upon reception of an alarm initiated by a perimeter sensor at unmanned DCS sites, tower vaults and equipment buildings shall be monitored acoustically through microphone sensors. If an attempted or actual penetration is sensed through the microphone sensors or through balanced magnetic door switches, the smoke generators specified shall be activated and the appropriate response force dispatched. (9) 5.1.3.5.7



TYPICAL APPLICATION OF DOOR AND WINDOW SENSORS.

guidance SECURITY/4 Zone 3**3. Waveguides**

All waveguides shall be armored in to protect against damage from penetrating tools and small arms fire. (9) 5.1.3.5.9

4. Antennas and antenna feeds

All antennas on DCS sites shall be protected by radomes. These radomes provide a visual obstacle to prevent small-arms attacks on the antenna feedhorns. (9) 5.1.3.5.8

**guidance SECURITY/4 Zone 3****b. Intrusion delay and building penetration resistance****1. Walls**

Walls of buildings, vaults, and other structures are usually considered more resistant to penetration and less desirable as targets for forcible entry than doors, windows, vents, and other conventional wall openings. However, most existing walls can be breached quickly if adequate tools are used and may be the optimal path for forcible entry. Explosives are especially effective in producing holes large enough to crawl through. Upgrading of existing walls or new wall designs can significantly extend the penetration delay against hand, power, or thermal tools. When explosives are used, upgrading or increasing the thickness of walls usually results in moderate delay increases; however, the amount of explosives needed increases exponentially with wall thickness. Upgrading walls or using advanced designs can also selectively increase tool requirements and force an attacker to alter the methods of operation. Combinations of tools, for example, power and hand tools or explosives and power tools, are often required to penetrate walls. The selection of the best tools or combinations of tools is essential to shorten penetration times. In evaluating wall penetration, it is assumed a team of attackers will use the optimal tools and will be skilled in their use.

The most common types of walls at existing facilities are: reinforced concrete, expanded metal-concrete, concrete block, clay tile, precast concrete tee sections, corrugated asbestos, sheet metal, and wood frame.

In general, a reinforced concrete wall is the only design option for cases in which a single barrier penetration time requirement exceeds 30 minutes. A conventionally constructed, reinforced concrete wall is probably the most cost-effective option to meet these longer penetration times with a single barrier approach. Reinforced concrete, of course, can also be used for single barrier penetration time requirements under 30 minutes. However, in these lower penetration time regimes, equivalent options are limited to attack-hardened cross sections.

Conventionally constructed masonry and stud/girt walls are only effective for penetration time requirements below 8 minutes (masonry) and typically less than 2 minutes, at most 2 to 5 minutes (stud/girt). When equivalent reinforced concrete, masonry, or stud/girt design options are available, the designer should select the option that best satisfies cost, functional, dimensional, and aesthetic objectives. If a single barrier approach is ineffective, the tables in section 2 or reference 37 can be used to evaluate the cost-effectiveness of multiple wall barriers. (37) 13.1-31

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Reinforced concrete--Because of their structural reputation and rugged appearance, concrete walls are almost universally believed to be formidable barriers. However, testing has shown that standard reinforced concrete walls are vulnerable to rapid penetration when proper tools and methods are used.

Concrete walls are designed to support structural loads and, except for vault walls, are not designed specifically to thwart penetration. In conventional construction, strength and thickness of concrete and size and spacing of reinforcing materials are determined from structural requirements. There are many possible combinations of concrete thicknesses and strengths and reinforcing bar (rebar) sizes and spacing. It is impractical to test all configurations. Therefore, for evaluating penetration, it is often necessary to interpolate or extrapolate the desired data from wall cross sections that have already been analyzed.

Reinforced concrete. Representative construction options are cast-in-place, tilt-up, and precast walls. For cast-in-place walls, the forms are constructed vertically and the concrete is poured on site. Tilt-up walls are similar to cast-in-place walls, except they are constructed horizontally and then lifted up. Precast walls are constructed elsewhere and shipped to the site. These options may include the conventionally constructed walls or the steel-fiber-reinforced (hardened) concrete walls, as shown in the next figure.

Conventional construction. As the next figure shows, the thickness of typical cast-in-place, precast, or tilt-up walls may be as low as 3-1/2 inches (90 millimeters) to as high as 12 inches (300 millimeters). Precast and tilt-up walls typically adhere to this range, whereas cast-in-place walls typically begin at 4 inches (100 millimeters) and may reach as high as 30 inches (760 millimeters). The corresponding reinforcement may be as low as a single layer of No. 3 steel bars at 12-inch (300-millimeters) spacing each way, for the 3-1/2-inch (90-millimeter) or 4-inch (100-millimeter) walls, to as high as No. 8 bars at 3 inches (75 millimeters) each way at each face for the 12-inch (300-millimeter) wall. Concrete with compressive strengths between 3,000 pounds per square inch (21 millipascals) to 6,000 pounds per square inch (42 millipascals), and a steel rebar with a tensile strength between 40,000 pounds per square inch (275 millipascals) and 60,000 pounds per square inch (415 millipascals) are typically used. (37) 13.1-35

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Penetration times for conventional construction. It should be noted that, for conventional concrete materials, the penetration times range from 2 minutes to greater than 60 minutes. At the time this manual was written (1982), no data for hand, power, and thermal tool attacks on concrete walls exceeding 12 inches (300 millimeters) in thickness were available. However, one can expect these thicker walls to exceed a 40- to 45-minute penetration time level, with a 30-inch (760-millimeters) wall well above an hour. In general, reinforced concrete walls provide higher penetration times relative to stud/girt or masonry walls of comparable thickness. In terms of cost, they are generally comparable to masonry wall construction (RCI between 1.4 and 4.2; see note on Relative Cost Index) but may be up to twice as expensive as stud/girt. (37) 13.1-37

Hardening options. If additional penetration time is required, consider one or both of the following options:

1. Increase the thickness of the wall or rebar size, spacing, or number of layers. (37) 13.1-37

Reinforcement can be used to extend the penetration delay time in most designs. Even though concrete is penetrated by an explosion, the reinforcing material usually remains intact such that it must be removed before entry can be gained. Removing the rebar often requires more time than is needed to remove the concrete. Therefore, using additional rebar, increasing rebar size, or decreasing center-to-center rebar spacing can be advantageous. Grades of reinforcing steel range from 40 to 75 kips per square inch.

2. Use steel-fiber-reinforced (SFR) concrete. For the same wall thickness, SFR concrete generally provides higher penetration times. The following table gives penetration time estimates for 3-1/2-, 4-, 12-, and 30-inch (90-, 100-, 300-, 760-millimeter) walls using SFR concrete. The added penetration time for a given wall thickness gained by this option should be weighed against the added cost of SFR concrete, which has an RCI value at least 25 percent greater than conventional concrete. (37) 13.1-37

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REINFORCED CONCRETE WALLS, CONVENTIONAL HARDENED CONSTRUCTION.
(37) 13.1

12" (300 mm) #7 AT 12" (300 mm) O.C. EACH FACE #6 AT 12" (300 mm) O.C. EACH FACE 1" (25 mm) CLR (TYPICAL) 3-1/2" (90 mm) #3 AT 12" (300 mm) O.C. MINIMUM SIZE		
23	CONVENTIONAL	2
	PENETRATION TIME (min.)	
2.0	R C I	1.4
3	SFR HARDENED	6
	PENETRATION TIME (min.)	
2.5	R C I	1.75

guidance **SECURITY/4 Zone 3****REINFORCED CONCRETE WALLS, CONVENTIONAL HARDENED CONSTRUCTION.**
(37) 13.1

30" (760mm) #10 AT 3" (75 mm) O.C. EACH FACE #8 AT 6" (150 mm) O.C. 1" (25 mm) CLR (TYPICAL) MAXIMUM SIZE 4" (100 mm) #3 at 12" (300 mm) O.C. EACH WAY MINIMUM SIZE		
60	CONVENTIONAL	2.5
	PENETRATION TIME (min.)	
> 4.2	R C I	1.4
> 60	SFR HARDENED	7.5
	PENETRATION TIME (min.)	
5.25	R C I	1.75

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Note: A relative cost index (RCI) value is indicated for each construction option presented in this section. The RCI value is defined as the ratio of cost of a particular construction option relative to the cost of a predetermined base for each building component type, that is, walls, roofs, floors, doors, windows, and utility openings. For example, in the case of walls, the predetermined base cost is \$4.10 per square foot (\$44.09 per square meter) of hollow concrete masonry unit construction and for roofs and floors, the base cost is \$3.00 per square foot (\$32.26 per square meter) of panelized plywood on wood joist systems. The RCI has been introduced in this manual as a preliminary cost parameter for identifying significant cost trades among construction options. However, it should not be considered the only cost guideline for performing preliminary cost-effectiveness trade-offs among construction options. The RCI values presented in this section relate to individual construction components and costs, such as walls, floors, and roofs. The RCI values are not to serve as a substitute for determining actual comparative construction costs for a specified facility in a given locality. A more detailed cost analysis is necessary to verify and supplement the preliminary trade-offs that can serve to flag important security-related structural costs. (37) 13.1-5

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PENETRATION TIME CHART INDEX FOR FIGURES ON THE FOLLOWING PAGES.

Single layer

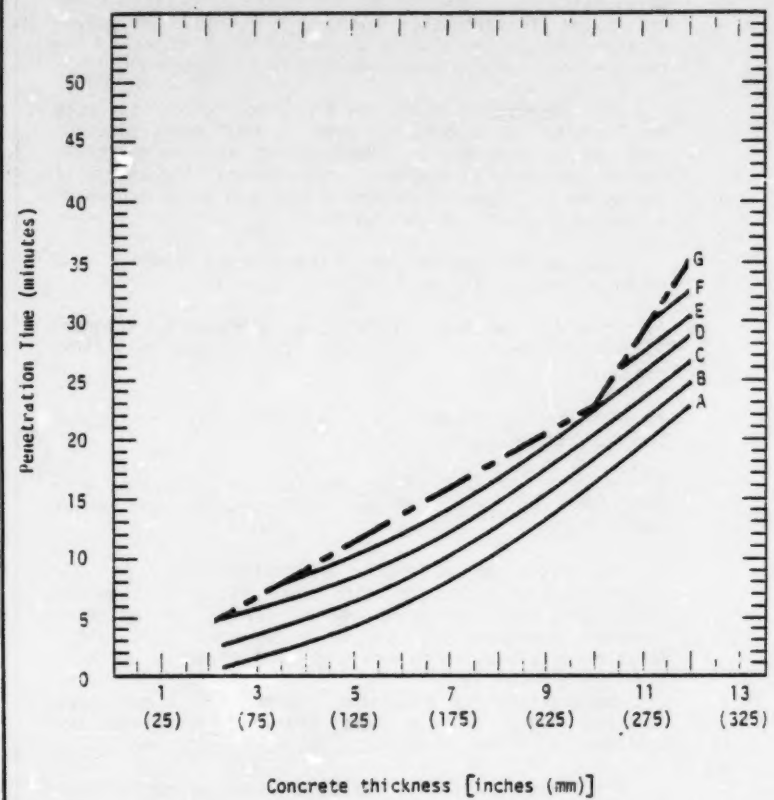
Spacing each way (inches) (mm)	Bar Number						
	None	3	4	5	6	7	8
3 (75)	A	B	B	C	C	D	E
3-1/2 (90)	A	B	B	C	C	D	E
4 (100)	A	B	B	B	C	C	D
4-1/2 (115)	A	B	B	B	C	C	D
5 to 9 (125 to 225)	A	B	B	B	B	B	C
>10 (250)	A	A	A	A	A	A	A

Double layer

Spacing each way (inches) (mm)	Bar number						
	None	3	4	5	6	7	8
3 (75)	A	C	C	D	E	G	I
3-1/2 (90)	A	C	C	D	E	G	I
4 (100)	A	B	C	C	D	E	G
4-1/2 (115)	A	B	C	C	D	E	G
5 to 9 (125 to 225)	A	B	B	B	C	C	D
>10 (250)	A	A	A	A	A	A	A

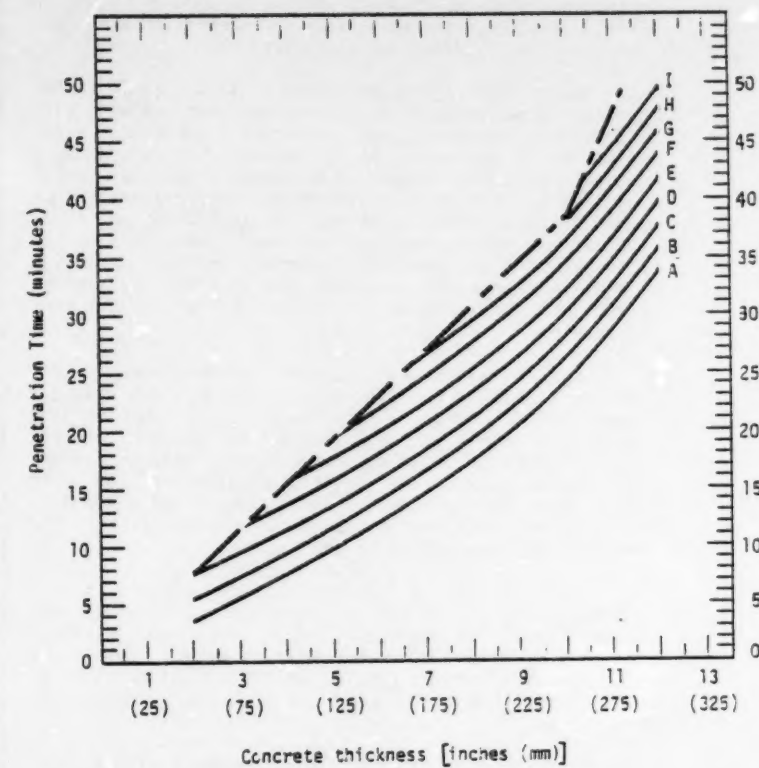
Note: The user of this table should note that curve F shown on the following page (left) and curves f and H shown on the opposite page (right) are not indicated because the interpolation required for inclusion in this table does not correspond precisely with No. 6, No. 7, or No. 8 rebar. The user, in applying curves F and H, should use the next subsequent letter in this table (for example, G instead of F, and I instead of H). (37) 13.1-39

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PENETRATION TIMES FOR REINFORCED CONVENTIONAL CONCRETE WALLS/ROOFS.
(37) 13.1-38

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PENETRATION TIMES FOR REINFORCED FIBROUS CONCRETE WALLS/ROOFS.
(37) 13.1-40

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Concrete wall thickness. Four-inch-thick reinforced concrete walls are common, but are not considered structural or load bearing. They are used as curtain walls to enclose the space between load-bearing structures such as columns. Concrete walls 6 inches or less in thickness are vulnerable to penetration with hand tools and small amounts of explosives.

Two or more reinforced concrete walls used in series provide longer penetration delay times than one wall with a thickness equal to their combined thicknesses. The walls should be separated by several feet (such as a natural hallway or room). Penetration of multiple walls requires multiple individual efforts and the transport of tools through preceding walls. If explosives are used, retreat and return times are additive. There is also the possibility that contained internal pressure from the explosive charge will collapse the roof or surrounding structures, thus presenting further barriers in the form of rubble.

Eight-inch-thick reinforced concrete walls are structural and load bearing and are commonly found in all types of structures. Hand tools alone require long penetration times and are ineffective against concrete wall thicknesses of 8 inches or more. Hand-held power and thermal tools are inefficient and require long penetration times; however, small amounts of explosives supplemented with hand tools, hand-held power tools, or thermal tools are effective and rapid.

Twelve-inch-thick reinforced concrete walls are commonly used in vaults and structures that store and protect sensitive materials. For 12-inch-thick walls, penetration times achievable with power and hand tools without explosives are considered impractical compared to penetration times achieved using these tools with explosives.

Concrete walls thicker than 12 inches that have been heavily reinforced can provide significant increases in penetration delay. Power, hand, and thermal tools are impractical for removing the large masses of concrete, but they can be used to cut and remove the reinforcing material after it is exposed by the explosives. Bulk or tampered explosives can produce large holes even in thick concrete walls, but do not effectively remove the reinforcing material. Cutting and removal of the reinforcing material to provide a hole large enough to crawl through are the main factors contributing to delay. Explosive platter charges can produce a crawl-through hole in the concrete and the rebar, however, this results in shorter penetration times, but requires large amounts of explosives and heavy plates.

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The size and weight of the explosive-platter charge required for single-shot penetration can become prohibitive because of the weight and because of the possibility of collapsing the entire structure or destroying its contents. However, if multiple explosive-platter charges were used to breach a thick wall, the penetration time could be expected to more than double.

An important advantage of using thick concrete barriers is the forced increase in tool sophistication required for penetration. Hand, power, and thermal tools can be used only to supplement explosives. The amount of explosives required to penetrate concrete walls increases exponentially with thicker walls.

Evaluation and testing of reinforced concrete wall sections lead to the following conclusions:

1. In spite of their formidable appearance, standard reinforced concrete walls can be penetrated fairly rapidly.
2. Reinforcing contributes significantly to total penetration delay.
3. Walls 6 inches thick or less can be penetrated with hand tools quickly. Thicker walls require much longer times.
4. Explosives are effective penetration tools for all concrete walls, but the size and weight of required explosives and associated plates (tamper or platter) increase exponentially as wall thickness increases. Penetration times can be extended by the thicker walls.

Suggestions for upgrading the barrier potential of existing walls or for consideration in design and construction of new structures, as appropriate, include--

1. The use of carefully evaluated depths of earth cover or other overburden material to delay access to the wall itself. Overburden is inexpensive, yet is effective against all methods of attack. Because of material availability and low cost, the denial of access to the wall by adding overburden is the most cost-effective way to protect concrete walls.
2. The use of concrete walls in series, separated by enough open space to require multiple penetrations. This method extends the total penetration delay exponentially.

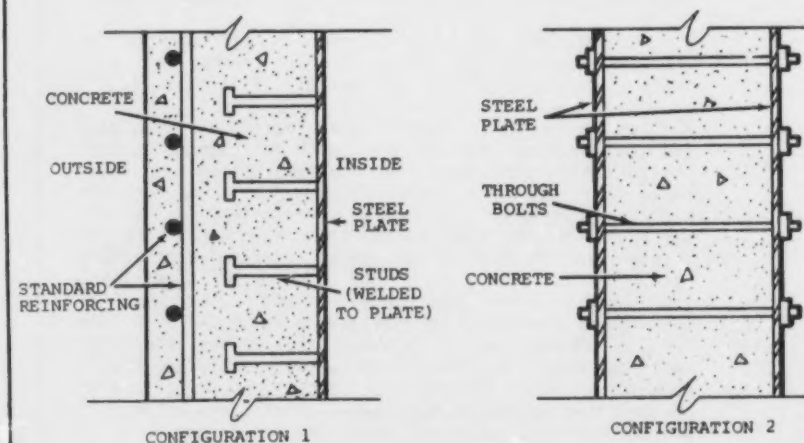
guidance SECURITY/4 Zone 3

3. The incorporation of large, closely spaced reinforcing materials into the design of barriers. This construction feature requires an attacker spend significant amounts of time cutting through or using inordinately large quantities of explosives or platter charges to accomplish removal.

4. The use of thick concrete walls to extend delay time and force required explosives to impractical limits.

Advanced concepts for reinforced concrete walls. In the design of new buildings to house sensitive items, new configurations of concrete walls and concrete mixtures should be considered. It is less expensive and more effective to use concrete walls of advanced design during initial construction than to attempt to upgrade standard walls later. Experience gained in the evaluation of existing concrete wall penetration resistance has let to research in advanced barrier concepts. Some possible improvements to concrete wall design are discussed below.

Steel-concrete sandwich walls. The figure below shows two proposed improvements for concrete wall vulnerability to penetration by explosives.



SANDWICH WALL (SECTION).

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Configuration 1 consists of a standard reinforced concrete wall with a steel plate attached inside the wall's surface. The plate can serve as the interior side of the form used for pouring the wall. It is secured to the concrete by studs or bolts welded to the plate. The use of hand, power, and thermal tools for penetration is a much more difficult and time-consuming task for this type of construction. When explosives are used to attempt penetration, the spalling that normally would occur on the inner wall surface is contained. The delay times, the amount of explosives required for penetration, or both increase. In the wall penetration tests, scaled 4-inch-thick walls similar to configuration 1 required five to six times as many explosives to penetrate as did similar concrete walls without plates.

Configuration 2 is similar to configuration 1, except that the steel plates are positioned at both interior and exterior surfaces of the concrete wall. The plates may be joined with through-bolts or by individual studs as in configuration 1. In configuration 2, the plates form the cavity into which the concrete is poured. This method should provide a wall section that effectively resists blast pressure, shock waves, spalling, and fragmentation that would be expected to defeat a standard concrete wall. Tests against a scaled version of configuration 2 also required approximately five to six times more explosives for penetration. However, if the plates' thickness is concentrated on the inside face (as in configuration 1), the explosive damage is slightly less for the same amount of explosives.

The cost of a sandwich wall would be approximately two to three times that of a standard reinforced concrete wall, but the steel plates could replace part or all of a separately constructed pouring form. If securely attached to the concrete, the plates might also function as reinforcement against structural tensile loads, thus decreasing the requirement for specialized reinforcing material. These two substitute functions performed by the plates serve to reduce the cost and thus may provide a cost-effective barrier.

Concrete block walls--Standard concrete block walls are easily penetrated with hand tools, power tools, or explosives. The strength and corresponding penetration times against power and hand tools can be greatly improved, however, by filling the hollow cores with concrete and reinforcing material. Various combinations of block walls backed with

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other structural materials and reinforcements have been evaluated for their effectiveness against penetration by hand and power tools. Little evaluation of explosives' effects on concrete block walls has been done; however, it is apparent that the amounts of explosives would be small and penetration times would be short.

Conventional construction. Unreinforced masonry wall construction typically consists of concrete masonry units, brick, structural tile, stone, or a combination of these materials. Concrete masonry units may range from 4 to 12 inches (100 to 300 millimeters) thick and may be left hollow or grouted solid. Single wythe brick generally comes in widths of 4 to 12 inches (100 to 300 millimeters). Structural clay tile will typically range from 4 to 8 inches (100 to 200 millimeters) wide, and stone will usually vary between 6 to 24 inches (150 to 600 millimeters). As for combinations of these materials, brick or concrete masonry units range from 8 to 16 inches (200 to 300 millimeters) with masonry tiles every second CMU course. Structural clay tile on CMUs may be found in widths of 6 to 16 inches (150 to 400 millimeters), again with masonry tiles every second course. Brick on structural clay tile vary from 8 to 12 inches (200 to 300 millimeters) with tiles every six brick courses. Finally, stone on CMUs range from 6 to 16 inches (150 to 400 millimeters) with tiles every second CMU course. Reinforced CMU varies from 6 to 12 inches (150 to 300 millimeters) wide, grouted solid with reinforcement ranging from No. 4 rebar at 32 inches (800 millimeters) on-center horizontally and 16 inches (400 millimeters) on-center vertically, to No. 5 at 16 inches (400 millimeters) on-center horizontally, and No. 8 at 6 inches (150 millimeters) on-center vertically. Brick on stone, double wythe, ranges from 10 to 16 (250 to 400 millimeters) on-center horizontally, to No. 9 at 12 inches (300 millimeters) on-center vertically. Reinforced CMUs with 4-inch (100 millimeter) stone or brick veneer vary from 10 to 16 inches (250 to 400 millimeters) wide, grouted solid, with reinforcement ranging from No. 4 rebar at 32 inches (800 millimeter) on-center horizontally and at 16 inches (400 millimeters) on-center vertically, to No. 5 rebar at 6 inches (150 millimeters) on-center horizontally and No. 8 at 6 inches (150 millimeters) on-center vertically. (37) 13.1-43

Penetration times for conventional construction. Conventional masonry walls provide only limited hardness against forced entry attacks using optimal combinations of hand, power, and thermal tools. They typically offer penetration times ranging from less than 2 minutes to 5 minutes. Even with thicker wall sections, only 8 minutes is required. Compared to other forms of construction, masonry walls provide penetration times only slightly

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greater than stud/girt construction. For the same wall thickness, masonry walls provide penetration times much less than reinforced concrete. In terms of cost, they are almost twice as expensive as stud/girt. (37) 13.1-43

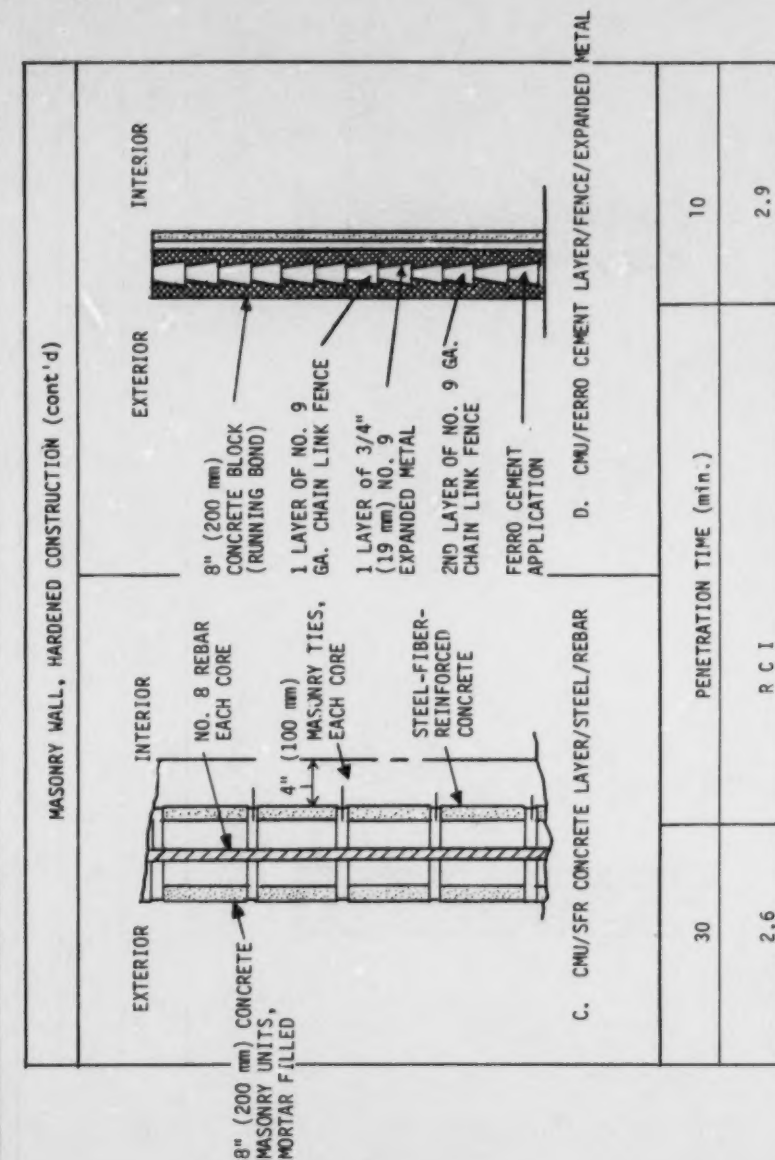
Conclusions on the penetration resistance of concrete block walls are that--

1. Concrete block walls alone are easily penetrated with hand tools.
2. The walls resemble the configuration of reinforced concrete walls if the hollow cores of the blocks are filled with mortar and include rebar, and penetration times are increased greatly against hand tools.
3. Upgrades for existing concrete block walls, and possibly new construction block walls, include a backing of several layers of expanded mesh, chainlink fabric, or reinforcing materials covered with 4 inches of concrete. Fibrous concrete and ferrocement appear to be especially effective backing materials.
4. Explosives can be used to penetrate concrete block walls, as with all existing concrete-type walls, quickly.

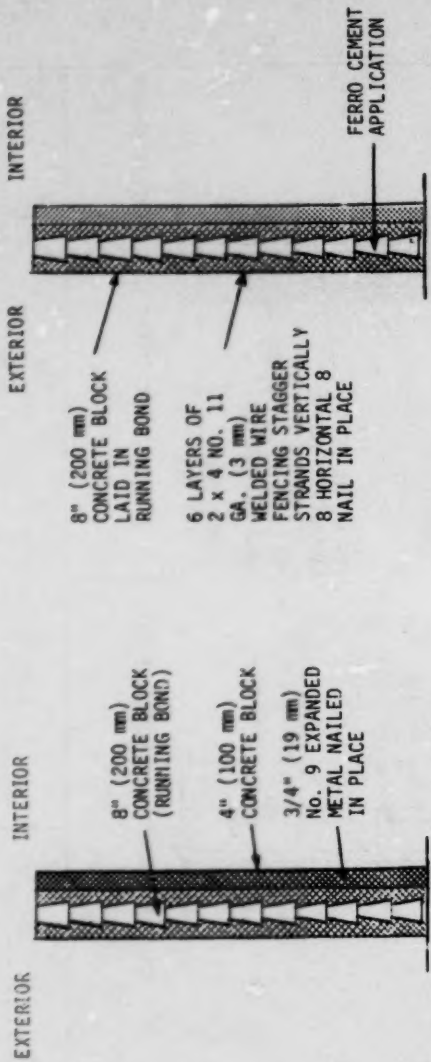
Hardening options. If additional penetration time is required, consider one or both of the following options:

1. Use reinforced masonry to increase wall thickness or the size, spacing, and number of rebar layers. All wall cavities should be filled with mortar. (37) 13.1-43
2. Use composites. Options were specifically designed and tested to provide improved attack resistance. Except for an option that uses a 4-inch (100-millimeter) layer of brick on a 4-inch (100-millimeter) layer of concrete block, all the other sections use 8-inch (200-millimeter) mortar-filled CMU blocks as the basic component. The CMU sections vary mostly in the type of reinforcing materials used. The data show that the only significant improvements in penetration times relative to conventional construction involve using a 3- to 4-inch (75- to 100-millimeter) layer of steel-fiber-reinforced concrete, which is either unreinforced or reinforced with expanded steel grating or steel rebar. These construction options provide penetration times between 25 and 30 minutes. However, they may be up to twice as expensive as conventional masonry construction of equivalent thickness. (37) 13.1-43

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guidance SECURITY/4 Zone 3

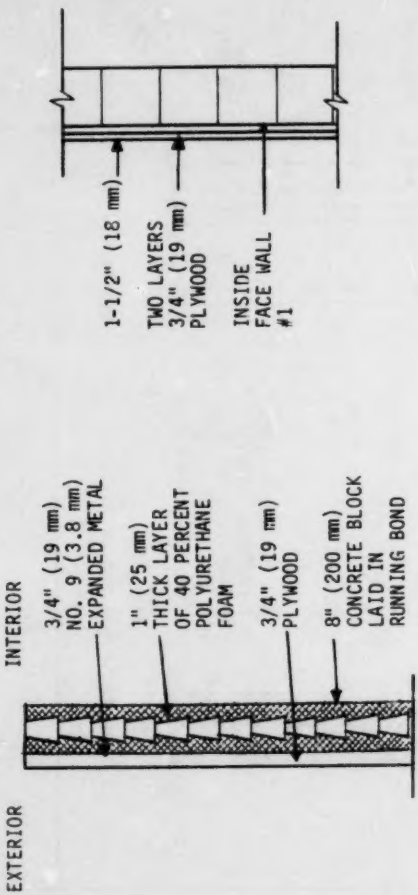


E. CMU/CONCRETE BLOCK/EXPANDED METAL

F. CMU/FERRO CEMENT LAYER/WIRE FENCING

5	PENETRATION TIME (min.)	10
1.5	R C I	2.7

guidance SECURITY/4 Zone 3

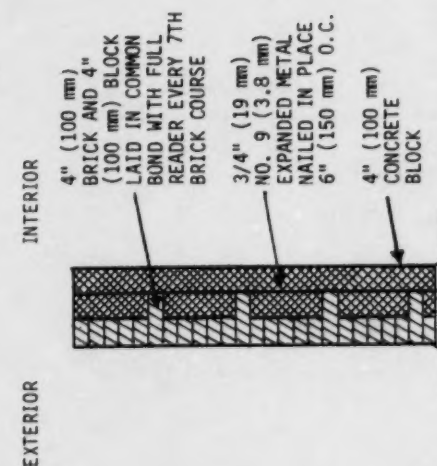


G. CMU/FOAM/PLYWOOD/EXPANDED METAL

H. CMU/PLYWOOD/ASPHALT PAPER

4	PENETRATION TIME (min.)	5
1.3	R C I	1.2

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1. BRICK/CONCRETE/BLOCK/EXPANDED METAL

PENETRATION TIME (min.)	R C I
4	2.4

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PENETRATION TIME CHART INDEX FOR THE FOLLOWING FIGURE:
CONVENTIONAL REINFORCED MASONRY WALLS (37) 13.1-43

Single layer of rebar

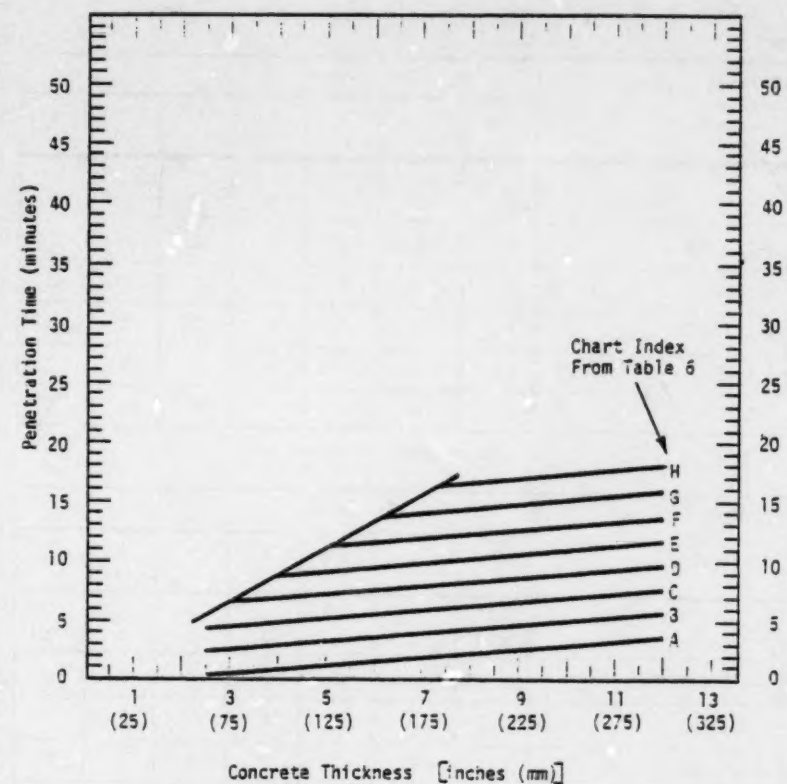
Spacing each way (inches) (mm)	Bar number						
	None	3	4	5	6	7	8
3 (75)	A	B	B	C	C	D	E
3-1/2 (90)	A	B	B	C	C	D	E
4 (100)	A	B	B	B	C	C	D
4-1/2 (115)	A	B	B	B	C	C	D
5 to 9 (125 to 225)	A	B	B	B	B	B	C
>10 (250)	A	A	A	A	A	A	A

Double layer of rebar

Spacing each way (inches) (mm)	Bar number						
	None	3	4	5	6	7	8
3 (75)	A	C	C	D	E	G	H
3-1/2 (90)	A	C	C	D	E	G	H
4 (100)	A	B	C	C	D	E	G
4-1/2 (115)	A	B	C	C	D	E	G
5 to 9 (125 to 225)	A	B	B	B	C	C	D
>10 (250)	A	A	A	A	A	A	A

Note: The user of this table should note that curve f, shown in the figure is not indicated because the interpolation required does not correspond precisely to either No. 6 or No. 7 rebar. The user should interpolate using the next higher letter in this table, for example, G instead of F.

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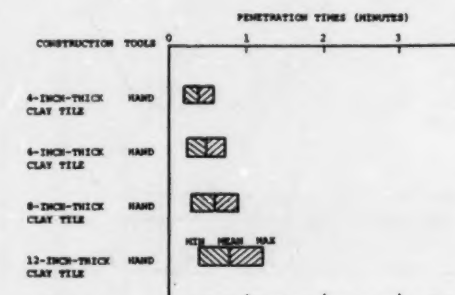
PENETRATION TIMES FOR REINFORCED MASONRY WALLS. (37) 13.1-44

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Clay tile--Clay tile walls have been used in some older buildings. This material is brittle and can be easily shattered. Only hand tools are needed to penetrate clay tile.

Conclusions about the penetration resistance of clay tile walls are that--

1. They offer little penetration delay against even simple hand tools.
2. The only feasible upgrade for existing clay tile walls would appear to be construction of new, harder walls, such as reinforced concrete, as a backup or replacement barrier.

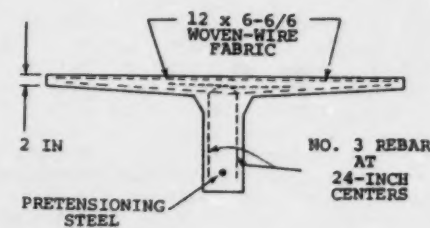


PENETRATION OF CLAY TILE WALLS.

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Precast concrete tee sections--Precast concrete tee sections are commonly used in building construction for walls, roofs, and floors. The figure shows a typical cross section of a tee section. The outer edge of the flange where the tees join is 2 inches thick. The stem of the tee is reinforced with No. 3 rebar and pretensioning steel, but the flange is reinforced only with 12-gage woven-wire fabric. Number 4 rebars, which are used to join sections, are cast into the flanges at an angle and are spaced widely.

From a barrier standpoint, the precast tee is similar to a thin concrete wall with woven-wire fabric. It can be penetrated with hand tools in about 0.8 minute.

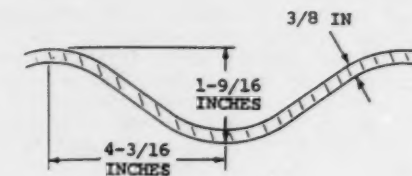


CROSS SECTION OF A TYPICAL TEE SECTION.

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Corrugated asbestos walls--This material is compounded of asbestos fiber and Portland cement. Corrugated asbestos is available in thicknesses ranging from 1/8 inch to 3/8 inch. Exterior curtain walls of 3/8-inch-thick corrugated asbestos can be found in existing buildings. The figure below shows a typical cross section of corrugated asbestos.

Corrugated asbestos walls cannot be considered significant barriers. The mean time to penetrate such a wall with hand tools is approximately 0.4 minute. One possible upgrade for a wall of this type would be to construct a reinforced concrete backing (or an equivalent structure) thick enough to provide the penetration delay required.



CORRUGATED ASBESTOS--TYPICAL CROSS SECTION.

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Stud or girt wall--Stud walls are used to construct wood or light metal frame buildings. The basic frame consists of wood or metal vertical supports, usually 2 by 14 inches (50 by 100 millimeters) or 2 by 6 inches (50 by 150 millimeters), placed 12, 16, or 24 inches (300, 400, or 600 millimeters) on-center. Metal girts are horizontal framing members used in rigid frame systems. They range in depth from 6-1/2 to 9-1/2 inches (165 to 240 millimeters) and are spaced 2 feet to 7-1/2 feet (600 to 2250 millimeters) on-center. An architectural finish is attached to the exterior side of the stud or girt, and an interior wall finish may be used on inside. (37) 13.1-46

Conventional construction. Seven basic types of stud/girt wall construction are: stud and stucco, stud and wood siding, stud and plywood siding, stud and shingle siding, stud and composition siding, stud/girt industrial siding, and conventional masonry veneer. (37) 13.1-46

Penetration times for conventional construction. Estimated penetration times for the seven basic types of stud/girt walls are less than 2 minutes against optimal combinations of hand and power tools. Use of 2 by 6 inch (50 by 150 millimeter) studs increases the penetration time insignificantly. Conventional masonry veneer walls offer penetration times of 5 minutes or less against optimal combinations of hand and power tools. In terms of cost, stud/girt walls are comparable to hollow, unreinforced CMU construction, depending on the architectural finishes selected. In terms of cost, masonry veneer walls have an RCI of 1.4 to 2.2. (37) 13.1-46

Hardening options. If additional penetration time is required, test data indicate that stud/girt construction can be greatly improved by using one or more of the following options:

1. Use stud and wood siding. However, sheet steel, expanded metal, ferro cement, or 2 by 6 inch (50 by 150 millimeter) studs stacked side-by-side and nailed to each other does not add appreciably to the 2 minutes of penetration time provided by conventional stud/girt construction. (37) 13.1-46

guidance SECURITY/4 Zone 3

2. Use wood and steel combinations. Layered sheet steel and wood combinations can double or triple penetration times (see the next table). The very limited test data indicate that a layer of 3/4-inch (19-millimeter) plywood sandwiched between two layers of 10-gage (3.4 millimeter) hot rolled steel provides approximately 5 to 10 minutes of penetration time. The penetration time can be increased approximately 5 minutes by adding another wood/steel layer. Presumably, this rule of thumb would apply to the addition of more layers until the overall thickness of the wall rendered use of hand and power tools impractical. Further gains in penetration time can be achieved by changing the steel layers to 9-gage (3.8 millimeter) ASTM 607 HS low alloy steel. One layer of 3/4-inch (19-millimeter) plywood sandwiched between two layers of that steel provides 15 minutes penetration time. Adding layers of 90-pound (41-kilogram) gravel finish roofing paper between the plywood and steel increases the penetration time to approximately 20 minutes. Adding more wood and steel layers to the sandwich reduces the effectiveness of the optimal mixture of attack tools. Increasing the plywood thickness by using a "fire door" design approach, such as layers of redwood, would further decrease the effectiveness of an optimal attack. Alternate layers of 3/4-inch (19 millimeter) plywood and 9 gage (3.8 millimeter) ASTM 607 HS low alloy steel, as noted above, also provide significant penetration resistance against attacks. To determine the penetration resistance and cost-effectiveness of these steel/ply composites and to learn what are considered the optimal composites of various materials, layers, and spacings, the security engineer should contact: Naval Civil Engineering Laboratory (NCEL), Naval Construction Battalion Center, Port Hueneme, CA 93043. (37) 13.1-46

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STUD AND WOOD SIDING, HARDENED. (37) 13.1-47

INTERIOR

EXTERIOR

INTERIOR

EXTERIOR

BEVEL SIDING WITH MIN 1-1/2" (38 mm) LAP JOINTS

1-LAYER 15# FELT PAPER

1 x 6 SHEATHING DIAGONALLY LAID

2 x 4 STUD 16" (400 mm) O.C.

PARTITION

3/8" (9 mm) GYPSUM WALLBOARD

3/4" (19 mm) PLYWOOD

1/16" (2 mm) SHEET STEEL

ANCHOR TO STUDS USING 10d ANNUAL RING (ANCHORFAST) NAILS SPACED 4" (100 mm) O.C.

BEVEL SIDING WITH MIN 1-1/2" (38 mm) LAP JOINTS

1-LAYER 15# FELT PAPER

1 x 6 SHEATHING DIAGONALLY LAID

2 x 4 STUD 16" (400 mm) O.C.

PARTITION

3/8" (9 mm) GYPSUM WALLBOARD

3/4" (19 mm) PLYWOOD

3/4" (19 mm) NO. 9 EXPANDED METAL

3/4" (19 mm) PLYWOOD

A. SHEET STEEL LAYERING

B. EXPANDED METAL LAYERING

	INTERIOR	EXTERIOR
Penetration Time (min.)	< 2 - 5	< 2 - 5
RCI	1.5	1.6

guidance

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C. FERRO CEMENT APPLICATION

D. 2 x 6 INCH STUDS STACKED AND NAILED

INTERIOR

EXTERIOR

INTERIOR

EXTERIOR

BEVEL SIDING WITH MIN 1-1/2" (38 mm) LAP JOINTS

1-LAYER 15# FELT PAPER

1 x 6 SHEATHING DIAGONALLY LAID

2 x 4 STUD 16" (400 mm) O.C.

PARTITION

3/8" (9 mm) GYPSUM WALLBOARD

6 LAYERS OF 2 x 4 NO. 11 GA. WELDED WIRE FENCING STAGGER STRANDS VERTICALLY 8 HORIZONTALLY 8 NAIL IN PLACE.

FERRO CEMENT APPLICATION

BEVEL SIDING WITH MIN 1-1/2" (38 mm) LAP JOINTS

1-LAYER 15# FELT PAPER

1 x 6 SHEATHING DIAGONALLY LAID

2 x 4 STUD 16" (400 mm) O.C.

PARTITION

3/8" (9 mm) GYPSUM WALLBOARD

2 x 6 STACKED SIDE BY SIDE 8 NAILED TO EACH OTHER 8 TO THE FRAMING

	INTERIOR	EXTERIOR
Penetration Time (min.)	< 2 - 5	< 2 - 5
RCI	2.6	2.0

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PENETRATION TIME CHART INDEX FOR THE FOLLOWING FIGURE

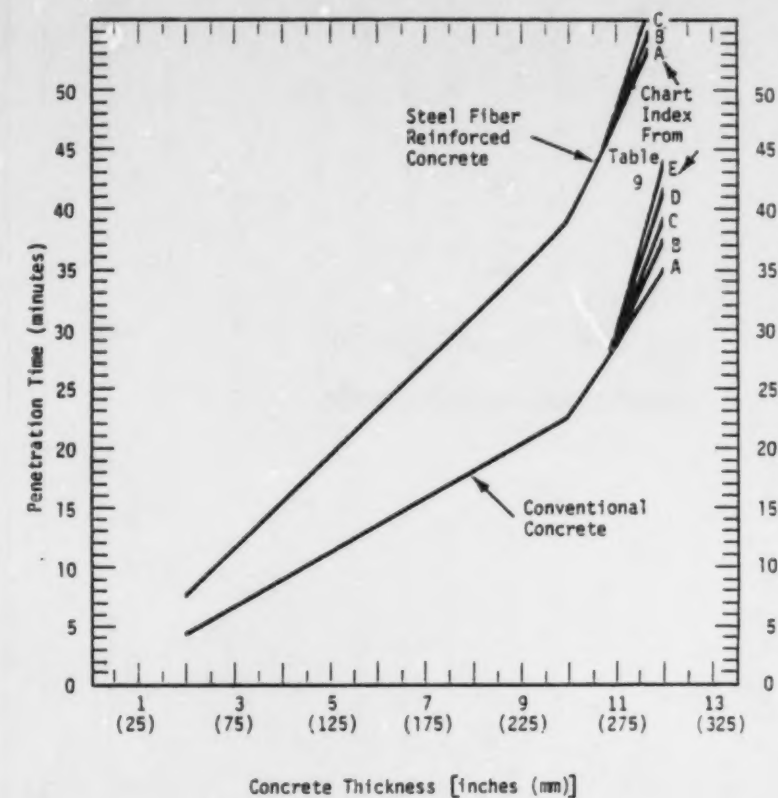
Single layer

Spacing each way (inches) (mm)	Bar number						
	None	3	4	5	6	7	8
3 (75)	A	B	B	C	C	D	E
3-1/2 (90)	A	B	B	C	C	D	E
4 (100)	A	B	B	B	C	C	D
4-1/2 (115)	A	B	B	B	C	C	D
5 to 9 (125 to 225)	A	B	B	B	B	B	C
>10 (250)	A	A	A	A	A	A	A

Double layer

Spacing each way (inches) (mm)	Bar number						
	None	3	4	5	6	7	8
3 (75)	A	C	C	D	E	E	E
3-1/2 (90)	A	C	C	D	E	E	E
4 (100)	A	B	C	C	D	E	E
4-1/2 (115)	A	B	C	C	D	E	E
5 to 9 (125 to 225)	A	B	B	B	C	C	D
>10 (250)	A	A	A	A	A	A	A

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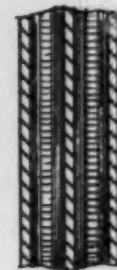
PENETRATION TIMES FOR REINFORCED CONVENTIONAL AND FIBROUS CONCRETE FLOORS. (37) 13.1-53

guidance SECURITY/4 Zone 3

WOOD AND STEEL ATTACK RESISTANT WALL SYSTEM. (37) 13.1-48



A. TWO-LAYER SYSTEM;
TWO LAYERS OF STEEL
WITH ONE LAYER OF
PLYWOOD IN THE MIDDLE



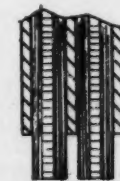
B. THREE-LAYER SYSTEM;
THREE LAYERS OF STEEL
WITH A LAYER OF
PLYWOOD BETWEEN EACH
LAYER

5 - 10	PENETRATION TIME (min.)	5 - 15
2.0	R C I	2.6

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C. TONGUE-AND-GROOVE THREE
LAYER PREFABRICATED
ASSEMBLY CONSTRUCTION



D. TWO-LAYER SYSTEM WITH
CRAVEL FINISH ROOFING
PAPER



5 - 15	PENETRATION TIME (min.)	15 - 20
2.1	R C I	2.0

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Advanced wall design concepts--Walls can be designed to increase penetration delay against hand or power tools. If an explosive is used as the attack tool, advanced wall designs that will appreciably extend the penetration delay are more complex and more expensive to construct. However, increasing the barrier potential of wall designs through advanced techniques will also force the attacker to use more sophisticated tools and methods.

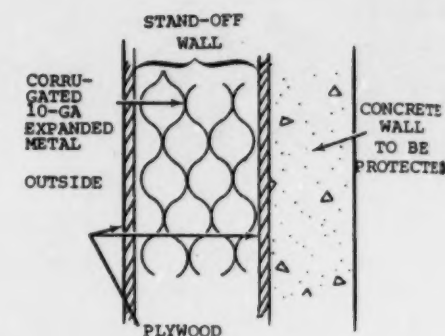
Fibrous concrete. This is not a new material but has had increased use in the last decade. It is used mainly for airport runways and roads for which impact loads and surface wear are experienced. Its cost is approximately twice that of standard reinforced concrete.

The composition of fibrous concrete varies, but it essentially consists of a concrete matrix containing a random dispersion of small steel fibers ranging from 0.006 to 0.030 inch in diameter and 0.25 to 3 inches long. The steel fibers toughen the concrete, increase its resistance to impact and shock loads, and increase the flexural strength to 40 to 60 percent of the compressive strength (standard concrete flexural strength is 20 percent of the compressive strength). Tests with hand tools have shown that the penetration delay time provided by fibrous concrete is twice that of standard reinforced concrete. The penetration delay time against attack with power tools is slightly greater for fibrous concrete than for standard reinforced concrete. Explosives attacks, however, proved equally effective against fibrous concrete and standard reinforced concrete.

Stand-off walls. An obvious method for protecting concrete walls from rapid penetration by explosives or for complicating the penetration is to attenuate the explosive energy reaching the wall. A concept for preventing the attachment of explosives directly to the surface of a wall has been investigated. When detonated a distance from the walls, the explosive force against the wall is reduced because the explosive pressure decreases.

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The stand-off wall forces the attacker into a choice of at least three courses of action: (a) more explosives must be placed at a distance from the surface of the concrete, (b) time must be spent using hand or power tools or explosives to remove the stand-off wall, or (c) a bulky platter charge must be used. The figure below shows a cross section through the concrete wall with the stand-off wall attached to the outer surface.



CROSS SECTION OF STAND-OFF WALL.

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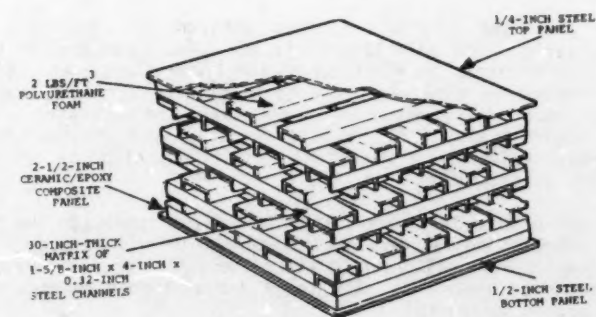
Lattice walls--To overcome the vulnerability of bulk concrete walls, including brittleness, susceptibility to fracture, and spalling, an experimental wall panel constructed of numerous connected individual metal channels was made and tested.

Individual channels were stacked as shown below and welded at their intersections. Steel plates were attached to the front and back to enclose the lattice configuration. Low density, rigid foam was injected into the empty spaces to provide additional penetration resistance. A ceramic/epoxy composite panel was included in the rear face to impede projectile and thermal tools.

Tests indicate that the panel can resist penetration by hand, power, or thermal tools for long periods because individual interconnected structural elements must be removed. Also, smoke and heat produced by the foam when thermal tools are used make working conditions difficult. Explosives attacks penetrated the panel but left jagged holes. Details on the panel and tests are reported in the references below. A wall of this type would be expensive to construct, but simplification of the construction methods and less expensive materials could reduce the cost.

G. W. Dyckes, "Penetration Tests of ICV Wall Panels (U)" (Albuquerque: Sandia Laboratories, November 20, 1975). Internal memorandum (CNSI).

I. B. White, "Follow-On Tests of ICV Wall Panels" (Albuquerque: Sandia Laboratories, February 10, 1976). Internal memorandum (CNSI).



PENETRATION RESISTANT PANEL.

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2. Roof and floor penetration resistance

Construction methods and materials used for roofs and floors are similar. The basic materials vary slightly in total thickness, type and quantity of steel reinforcement, and concrete strength required to carry the loads (designated "live" and "dead" loads). In general, floors offer more resistance to penetration than roofs do because floors are protected by the main structure and are designed to accommodate heavier loads than roofs. A floor may be considered a roof with the membrane and insulation removed. Contemporary roof types used on many structures include--

Type 1: Prestressed concrete tee beams with lightweight concrete, insulation, and a roofing membrane.

Type 2: Metal subdeck with reinforced concrete, insulation, and a roofing membrane.

Type 3: Metal roof deck with lightweight concrete, insulation, and a roofing membrane.

Type 4: Metal roof deck with insulation and a roofing membrane.

Type 5: Metal roof with insulation below.

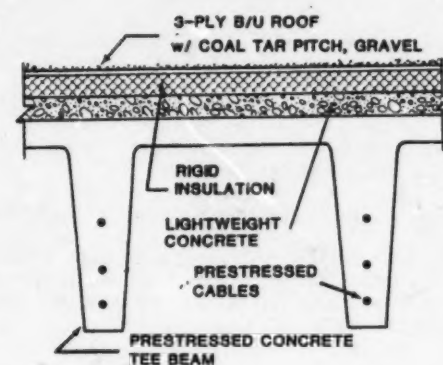
Type 6: Reinforced concrete beams and slab with insulation and a roofing membrane.

Type 7: Wood sheathing with a roofing membrane.

The designation of types 1 through 7 has been adopted solely to facilitate discussion in this section. The definitions of these types are not complete descriptions for the different roofs.

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Type 1: prestressed concrete tee beam--A type 1 roof is constructed with prefabricated, prestressed concrete tee beams, lightweight concrete, rigid insulation, and a three-ply, coal tar pitch, built-up roofing membrane with gravel. The Type 1 roof gives the appearance of a structure that should provide good penetration resistance (see figure). The tee beams are formed in different lengths and depths, as required by the load capacity; the web is reinforced with stressed reinforcing cables. The flange is usually constructed with 10-gage, 6 by 6 inch welded wire fabric (WWF). The normal method of attachment consists of welding the bearing surfaces at the base of the web to the structural framing. The flange joints are secured to each other at the shear ties, which are cast into the beams during fabrication. The number of shear ties, usually a minimum of four, is determined by the length of the beam. The lightweight concrete is installed with no reinforcement (usual construction practice) and with the insulation and roofing membrane.



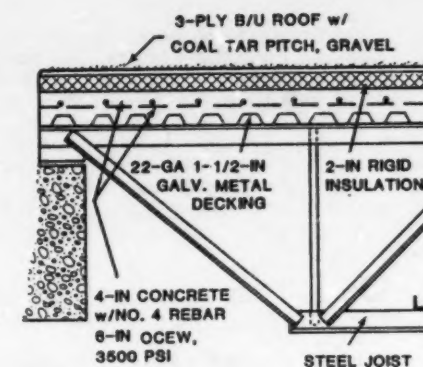
TYPE 1: PRESTRESSED CONCRETE TEE-BEAM CONSTRUCTION.

This type of construction is vulnerable to penetration by some hand tools, power tools, and combinations. Penetration time is approximately 3.5 minutes. The most vulnerable areas for penetration are the tee beam and joint flanges, if the adversary can find them.

When explosives are used, the beam can be penetrated through the flange area in approximately 1 minute. Attempts to sever the prestressed steel in a tee-beam web using linear-shaped charges and 5-pound bulk charges have proved unsuccessful. Penetration is possible without beam failure; however, safe occupancy of a facility would be questionable after this type of penetration.

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Type 2: metal subdeck and reinforced concrete--A Type 2 roof is constructed with a ribbed metal subdeck, standard reinforced concrete, rigid insulation, and a three-ply, coal tar pitch, built-up roofing membrane with gravel. The Type 2 roof is considered a substantial roof (see figure below). The metal subdeck is installed on the metal joists and welded together with the ends overlapped approximately one rib section. Standard 3500-pounds per square inch reinforced concrete is used. The concrete is 4 inches thick and contains No. 4 steel rebar spaced 6 inches on-center each way. The rigid insulation and roofing membrane applied to the Type 2 roof slab are the same as those used in the type 1 roof.



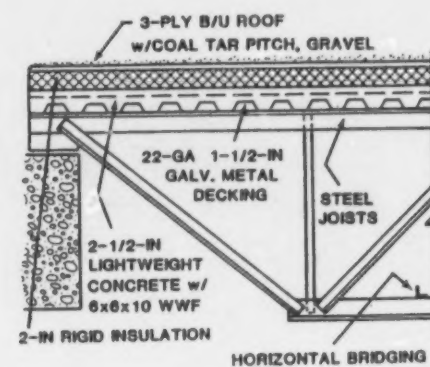
TYPE 2: METAL SUBDECK AND REINFORCED CONCRETE.

The Type 2 roof provides substantial resistance to penetration when only hand tools are used: penetration time is approximately 30 minutes. A penetration was completed in 15 minutes by an attack team equipped with a combination of hand, power, and thermal tools. However, the excessive weight of such tools (970 pounds) greatly complicates their transportation to a roof, making the practicality of this method questionable.

When bulk or linear-shaped explosives are used, the time for penetration may decrease to approximately 2 minutes. The deformed bar is still intact after the explosion, however, and attempts to remove it with small linear-shaped charges have not proven successful.

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Type 3: metal roof deck with lightweight concrete--A Type 3 roof is constructed with a metal roof deck, reinforced lightweight concrete, rigid insulation, and a three-ply, coal tar pitch, built-up roofing membrane with gravel (see figure below). The Type 3 roof is used on structures that have a moderate roof load. This roof is similar to Type 2 in construction except that the reinforced concrete is replaced by reinforced lightweight concrete that contains an aggregate of Zonolite, pumice, or similar materials with a loose weight of 70 pounds per cubic foot or less. Concrete reinforcement consists of 10-gage, 6 by 6 inch WWF.

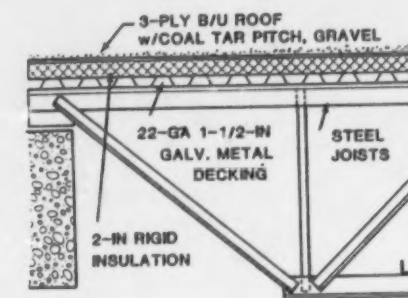


TYPE 3: METAL ROOF DECK WITH LIGHTWEIGHT CONCRETE.

The Type 3 roof can be penetrated with hand tools in less than 3 minutes. The lightly reinforced concrete can be removed from the subdeck in large pieces and penetrated easily with a fire axe. Penetration is possible in approximately 45 seconds using 1 pound or less of explosives.

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Type 4: metal roof deck with insulation--The Type 4 roof is constructed with a metal roof deck, rigid insulation, and a three-ply, coal tar pitch, built-up roofing membrane with gravel (see figure below). The Type 4 roof is used on light structures. The three roof elements (membrane, insulation, and main deck) are discussed in the previous paragraphs.

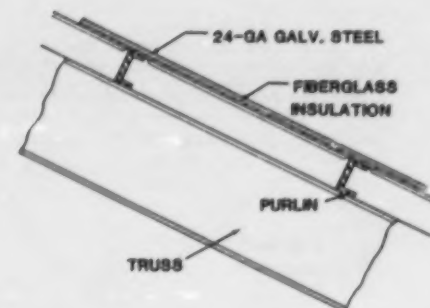


TYPE 4: METAL DECK WITH INSULATION.

The Type 4 roof is vulnerable to penetration by hand and power tools in less than 2 minutes. An explosives penetration requires approximately 1 minute.

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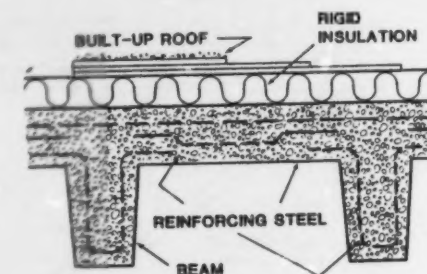
Type 5: metal roof (insulation below)--Type 5 roofing is constructed of 24-gage corrugated metal with 1-1/2 inches of fiberglass insulation and a wire fabric (see figure below). The Type 5 roof is used on most metal buildings, although it has very little resistance to penetration. This roof can be penetrated with hand tools in less than 40 seconds.



TYPE 5: SHEET METAL CONSTRUCTION.

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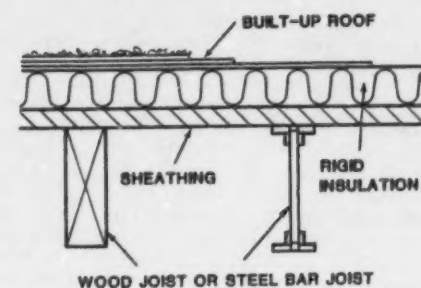
Type 6: reinforced concrete beam and slab--The Type 6 roof is constructed with heavily reinforced concrete beams, a concrete slab for the main roof deck, rigid insulation, and a built-up roofing membrane (see figure below). The Type 6 roof is used on some multistoried facilities and offers better resistance to penetration than most other roofs. The main deck may be 6 inches deep or more with multiple layers of reinforcing steel, making it similar in construction to a wall. This type of roof may preclude the use of hand and thermal tools if entry into the building must be made in less than 30 minutes. Explosives penetration is possible in 3 minutes.



TYPE 6: BEAM AND SLAB CONSTRUCTION.

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Type 7: wood sheathing with membrane--The Type 7 roof consists primarily of wood materials and contains a wood sheathing, rigid insulation, and a built-up roofing membrane (see figure below). It is inexpensive and hence is commonly used in many small structures, although its use is discouraged by most fire codes. Penetration by hand tools is possible in less than 2 minutes and in approximately 1 minute if explosives are used.



TYPE 7: WOOD CONSTRUCTION.

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Roof upgrades: vulnerability and enhancements--Many enhancements can be added to the seven types of roofs and their elements. Enhancements suggested in this handbook do not apply directly to any one roof type, but rather to the roof elements. Below-the-roof-line enhancements are also discussed. Roof enhancements can be combined to increase delay time when a penetration threat (type of tools) is defined for an individual roof. Many of the suggested element enhancements have not been evaluated, however, and the increase in delay time is estimated to be only tens of seconds. Some element enhancements may double the penetration time and combinations of element enhancements may more than double a roof penetration time against some threats. However, the most cost-effective enhancements appear to be those placed below the roof line, could be applied to either new or existing facilities.

Membranes. The membrane consists of a three-ply roofing felt with either coal tar pitch or roofing asphalts and gravel or slag embedded in the flood coat. It is vulnerable to hand and power tools and can be peeled away in large sections to expose the next roof element.

The membrane has inherent penetration deterrents such as the ability to foul some cutting tools. Because it can self-heal, coal tar pitch may be more suitable for this function than roofing asphalts on some facilities.

The installation of a screen or grid such as a 4-gage, 3/4 by 3/4 inch screen embedded in the flood coat of bitumen above the felts can delay breaching of the second roof element. Such a screen enhancement should be secured to the main deck to prevent easy removal. When concealed in the flood coat, it might force the use of other kinds of tools. The flood coat of bitumen can also be increased from its normal weight (60 pounds of asphalt or 70 pounds of coal tar pitch per 100 square feet) so that gravel or slag can be deeply embedded to increase cutting resistance.

The membrane can be removed in less than 30 seconds using hand and light power tools. The installation of a screen or grid may eliminate use of some hand tools and force the use of power tools. This change may increase the element penetration time to approximately 1 minute. When explosives are used, enhancement of this element would not significantly increase delay time.

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Insulation. Rigid insulation board can be penetrated with many types of hand and power tools and removed in large pieces if it is not secured to the main or subroof deck. When the insulation is 2 inches thick or less, it is usually a frangible material.

The insulation functions as a roof enhancement by reducing the impact energy from tools and the force of some explosives. It also limits the effective cutting depth of a tool. Adding several inches of rigid insulation increases the roof's energy absorption and increases the depth of material to be cut and removed, thus increasing penetration delay. Four inches or more of rigid insulation secured to the main deck can increase hand- and power-tool penetration by 15 to 30 seconds.

Rigid insulation can be lifted by winds blowing over a roof and, therefore, to meet building codes, the insulation must be adequately secured. In effect, this added securement is an enhancement. The insulation is secured by installing fasteners through it and attaching these fasteners to the main deck. There should be one fastener for every 2 square feet of insulation. For added enhancement, the amount of free (unsecured) area of insulation can be further reduced by increasing the number of fasteners to one for each square foot of insulation. To insure adequate penetration delay, the insulation retainers must be secured to the main roof deck. The previously suggested screen or mesh for the membrane may also function as an enhancement to insulation.

When an additional thickness of insulation is used, it can be sandwiched and used to conceal other deterrents, even some form of dispensable deterrent.

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Main decks

Lightweight concrete. Unreinforced, lightweight concrete can be readily removed with some hand tools and with cutting tools. Light reinforcement such as 10-gage, 6-inch WWF adds no significant delay time to penetration.

Lightweight concrete should be a minimum of 4 inches thick. Standard reinforcement such as deformed steel bars and expanded steel mesh should be used in place of the light wire fabric. Standard deformed rebar provides better resistance to explosives than an expanded steel mesh (3 pounds per square foot) because the steel mesh tends to fail at the diamond points, areas of high stress concentration. However, when hand, power, and thermal tools are used, this enhancement may increase element penetration time by 100 percent.

Standard reinforced concrete. The standard reinforced concrete main deck is less vulnerable to penetration by hand tools than lightweight concrete; however, penetration can be completed quickly with either explosives or heavy power tools. If the concrete is unsupported on the lower side, spalling from impact energy is likely to occur. Reinforcing steel bars, when exposed, are vulnerable to removal by thermal tools and by hand tools when the bars are smaller than No. 5 (5/8-inch diameter).

Standard reinforced concrete can be enhanced using larger reinforcing steel formed into multiple rows or layers. A minimum rebar size of No. 6 (3/4-inch diameter) is suggested. This type of reinforcement forces a potential intruder to use more sophisticated tools. The concrete thickness and strength can be increased by changing the mix or by using additives.

Corrugated roof. This type roof is vulnerable to most hand and thermal cutting tools, explosives, and power tools. The fasteners that hold the sheets to the purlin can be removed or broken with forcing tools. Another vulnerable area is the joints between sheets; these joints are usually unprotected and unconcealed. Also, they often have too few fasteners, or else an inadequate method of fastening is used.

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When exposed fastening devices are used on corrugated roofs, the number of fasteners should be increased, the space between them should be reduced, and additional structural members with fasteners should be installed to reduce the clear span of material to less than human-size. Another enhancement is heavier gage roofing deck with locking seams at the joints of each sheet and with additional fasteners or thermal methods used to secure the roofing to the structural members. Such improvements will only increase the penetration delay by 10 seconds or less, however. Thus, a below-the-roof-line enhancement is suggested.

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Subdeck system

Metal systems. Many metal subdeck systems are vulnerable to penetration by cutting or impact after they have been exposed by penetration of the outer elements. The weak point in this element is the joint between sheets since sheets are normally fastened at the structural members, which may be as much as 4 feet apart. The metal is usually light gage (not very thick) and is easily bent to clear the opening after cutting.

To delay penetration at the deck joints, the joints could be secured with mechanical fasteners or by a continuous weld. A metal deck system used with locking joints would also delay penetration at the joint area. A heavier gage material that resists bending or cutting would be still another effective aid in penetration delay.

If additional penetration time is required, wood and steel combinations can be useful. As in stud/girt walls in Section 2, layered wood and sheet steel can greatly increase penetration time against hand and power tools. Limited test data indicate that a layer of 3/4-inch (19-millimeter) plywood between two layers of 10-gage (3.4-millimeter) hot rolled steel provides approximately 7 minutes of penetration time. This can be increased by approximately 5 minutes by adding another wood/steel layer. Additional testing shows that one layer of 3/4-inch (19-millimeter) plywood sandwiched between two layers of 9-gage (3.8 millimeter) ASTM 607 HS low alloy steel, instead of 10-gage (3.4 millimeter) hot rolled, provides 14.5 minutes of penetration time. Adding layers of 90-pound gravel finish roofing paper between the plywood and steel further increases the penetration time to approximately 20 minutes. Adding more wood and steel layers to the sandwich reduces the effectiveness of optimal tool mixes. Increasing the plywood thickness by a "fire door" design approach, such as using layers of redwood, would further decrease the effectiveness of the optimal attack. Alternate layers of 3/4-inch (19-millimeter) plywood and 9-gage (3.8-millimeter) ASTM 607 HS, low alloy steel provide significant penetration resistance against optimal attacks. To determine the penetration resistance and cost-effectiveness of these steel/ply composites and to learn what are considered the optimal composites of various materials, layers, and spacings that have been tested, the security engineer should contact: NCEL, Naval Construction Battalion Center, Port Hueneme, CA 93043. (37) 13.1-56

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Precast concrete tee beams. The major vulnerability of tee beams is failure in the flange area resulting from impacts. The 3-inch nominal thickness of lightly reinforced concrete offers little resistance to impact or cutting.

One enhancement for precast concrete tee beams is reinforcement of the flange area with larger reinforcing steel in place of the light wire fabric normally used in fabrication. Adding deterrents above or below this element would increase the penetration delay time. When the enhancement is below the flange or web area, caution must be used in choosing the attachment method. The normal method for attachment to tee beams is to use unistruts, which are cast into the concrete. However, unistruts are often not designed for impact loads and could pull out.

Below-the-roof-line enhancements--Penetration tests have indicated that barriers placed below the roof are sometimes more effective against penetration than those in the roof itself. Such barriers can be used in some existing structures without major modification. Placing these enhancements below the roof line protects them somewhat against direct attack and could make a second penetration necessary. This second penetration might have to be done in a confined area and could force the use of tools from other classes.

The exact position of a barrier below the roof line is a factor in its effectiveness. When the enhancement is within 4 inches of the roof, it may be more vulnerable to a variety of tools; however, it may also prevent bending of the roof subdeck system. The optimal distance below the roof appears to be 10 to 12 inches. This distance can create a "hole" effect, that is, restriction of the operating space needed for the tool and the available space for crawl-through.

Enhancement materials range from quarry screen to expanded steel bank vault mesh or floor gratings. Tests have shown that the increased delay may exceed 250 percent for explosives and nonexplosives penetration methods for some added barriers. Penetration times for grilles, grids, and grates are given in the section following entitled, "Utility Openings." A potential enhancement could be the use of multiple-layer enhancement with layers of different hardnesses.

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Floor construction--The similarity in design and construction of roofs and floors, together with the preceding discussion of roof construction concepts, shows the need to present detailed information on floor construction. Fabrication includes an increase in size and strength of structural members to carry the increased live and dead loads, which are sometimes in excess of 500 pounds per square foot. This additional strength provides floors with greater penetration resistance than most roofs. Some finishing materials for floors, such as asphalt floor covering, contribute little to penetration resistance. Floors constructed below ground or on grade would require tunneling or the removal of a considerable excavation to achieve penetration.

Penetration modes similar to those used against roofs can generally work for floors; however, when a larger amount of explosives is required for penetration, there is the possibility that the overpressure from the detonation may cause structural failure to other elements. The amount of internal pressure a facility can withstand without a structural failure will have to be determined for each case.

Existing enhancements built into some floors, such as under-the-floor ducts for power and communication may increase resistance and reduce the clearance needed for a penetration. The installation of utility, plumbing, and heating and air-conditioning systems below the floors may also hinder penetration. Enhancements can also be added below the floors.

For buildings without basements, but with shallow footings and a slab-on-grade floor, the possibility of digging underneath the footing and penetrating upward through the floor should be considered, if the threat is overt. If the digging time plus the time for penetrating the slab are too low, consider pouring a reinforced concrete apron around the structure. The intruder will then be forced to attack the apron from above or tunnel under it. For covert threats, digging time should not be considered, since intruders will use stealth to dig their way to the floor. Therefore, the penetration time through a floor by a covert threat should only be based on the time it takes to penetrate the floor. (37) 13.1-55

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3. Doors

Penetration delay time through static structures can be increased by using thicker or composite materials. Doors, however, due to the functional requirements and associated hardware, impose design restrictions and often are one of the weakest links in a structure. For example, many buildings with heavy concrete walls provide pedestrian access through commercial hollow, steel doors. The barrier value of the basic structure is relatively high, but it is weakened by the use of ordinary doors, frames, and hinges that can be quickly penetrated.

Consequently, for an effective barrier, the principle of balanced design requires that doors with associated frames, hinges, bolts, and locking mechanisms be strengthened to afford the same penetration delay provided by floors, walls, and ceilings of the parent structure. Conversely, if the door assembly cannot be improved, it may not be cost-effective to upgrade the building structure.

With the exception of vault or blast doors, no standard pedestrian doors and associated hardware provide significant penetration resistance against determined adversaries. New designs are needed to provide doors that match the more rugged structures' penetration resistance.

For these reasons, the number of entrances to a facility should be reduced to an absolute minimum and, when more than one door exists, only one of these should be provided with outside mounted locks and entry hardware. All others should, as much as practical, present blank, flush surfaces to the outside to reduce their vulnerability to attack. Although the penetration time through the door surface can usually be increased by using heavier or composite materials, such hardening may impose serious limitations because of weight, functional requirements, mounting hardware, and lock vulnerability. (37) 13.1-62

Personnel doors--These vary in type, style, and class, but most common exterior doors are 1-3/4 inches thick with 16- or 18-gage (0.060- or 0.048-inch) steel surface sheets. Construction is usually hollow-core or composite with or without glass or louvers. A composite door core consists of noncombustible, sound-deadening material, usually polyurethane foam or slab. Light-gage vertical reinforcement channels are sometimes used inside hollow core doors to add strength and rigidity to the door assembly.

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Steel pedestrian doors are found throughout Government and private industry in single or double configurations and use a wide variety of locking devices. Exterior doors usually swing outward, regardless of their functional design, with closing devices attached internally. Hinges are mortised with either removable or nonremovable pins. Additional doors are provided for emergency exits, as required by fire and safety codes.

Requirements for panic-bar devices on all emergency exits make all doors only one-way barriers. This design requirement provides a variety of exit modes to outside attackers after a building has been breached.

Penetration time for lightweight sheet steel doors is essentially the same.

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DOORS, CONVENTIONAL CONSTRUCTION (37) 13.1-63

Door Construction	Penetration Time (minutes)
Sheet Metal Pedestrian Door 16 gauge (1.5mm) metal, panic hardware, cylinder lock, rim set, butt hinges with removable pins Hollow steel 16 gauge (1.5mm), narrow glass one side, louvers near bottom Hollow steel 18 gauge (1.2mm), half glass expanded metal 0.11 in (3mm) grill	<1
Sheet Metal Vehicle Door Hollow steel panel, 16 gauge (1.5mm) Roll-up steel, corrugated 16 gauge (1.5mm)	<1
Sheet Plate Magazine Door 1/4 in (6mm) steel plate, one padlock	<1
Steel Plate-Void-Steel Plate Magazine Door Two large hinged hasps for padlocking, 3/4 in (19mm) steel, 4 in (100mm) air space, 1/2 in (13mm) steel 3/8 in (9mm) steel, 3 in (75mm) air space, 0.036 in (0.9mm) steel, two padlocks on door 3/8 in (9mm) steel, 3 in (75mm) void, 1/4 in (6mm) steel plate, two locks	<1 <1 <1
Steel Plate-Insulation-Steel Plate Magazine Door 3/4 in (19mm) steel plate, 3 in (75mm) fiber-glass, 1/8 in (3mm) steel plate	2
Steel Plate-Sheet Metal Vault Door Class 5F filing cabinet drawer Class 5 vault door	<1

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Exterior personnel doors are commonly 1-3/4 inches (45 millimeters) thick and typically faced with 16- or 18-gage (1.5- or 1.2-millimeter) steel. Although some doors remain hollow, others are filled with a noncombustible foam or slab of polyurethane. Locking devices for personnel doors vary; however, they typically have five- or six-pin tumblers. Closing devices are usually attached internally and open to the outside. Hinges are mortised with nonremovable pins. Estimated penetration times for standard personnel doors are uniformly low as shown in the previous table. It should be noted that standard sheet metal personnel, vehicle, and steel plate magazine or vault doors result in a weak link that can seriously degrade the penetration time of an otherwise substantially hardened facility. Penetration times in most cases will not exceed 1 minute for a reasonably competent, well equipped intruder attacking a door with hand-held, power, or thermal tools. The insulated steel plate magazine door offers a slightly higher penetration of 2 minutes, as shown in the table. In evaluating door surface penetration times, the facilities engineer should consider doors required to have panic bar hardware as special cases. These doors do not require a human-sized opening to be defeated; drilling a small hole large enough through which to pass a wire hook is all that is required to open them. As noted above, the trade-offs between life safety and security may impact directly on interior layouts to avoid a design that must be compromised to meet fire protection requirements. (37) 13.1-64

Standard industrial doors are vulnerable to several attack modes. Improved designs are needed to upgrade the penetration resistance of industrial doors to match the delay provided by the remaining structure. Penetration times for industrial doors vary greatly; the minimum penetration time is about 10 seconds. Removal of internal panic bars is desirable but fire and building codes may disallow this.

Attack modes

Standard industrial doors are vulnerable to several attack modes. Improved designs are needed to upgrade industrial door penetration resistance to match the delay provided by the remaining structure. Penetration times for industrial doors vary greatly; the minimum penetration time is about 10 seconds. Removal of the internal panic bars is desirable, but fire and building codes may disallow this.

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Upgrades and improved design concepts

Steel pedestrian doors mounted in stamped steel frames are found at many facilities. These doors offer little resistance to forcible attack; however, they can be upgraded in various ways to increase their penetration delay time. The upgrades and design concepts described in the following subsections are for balancing the overall door structure, that is, the face, frame, hinges, exit devices, louvers, glazing, and locks, to protect against forcible penetration attempts with hand, power, or thermal tools. Penetration of these doors with explosives, even when they are upgraded, takes approximately 1 minute. Penetration by hand and power tools requires 1 to 2 minutes. Even though thermal tools are bulky and require 2 to 5 minutes for penetration, they could be used to cut a crawl-through hole in a door without triggering an alarm.

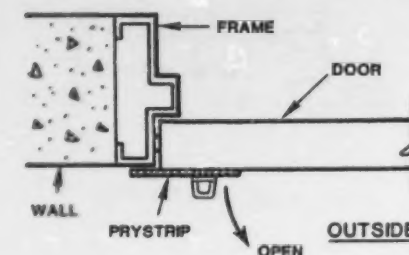
Eliminating all unnecessary doors is the first step in upgrading facilities. Eliminating all windows, louvers, and external knobs and key ways is another type of upgrade.

Steel plates. One structural enhancement is the addition of steel plates to door surfaces; this increases the door's penetration resistance to hand and light power tools. Heavy-duty hinges should be used to support added weight, and frames should be grouted to strengthen the supporting structure.

Redwood cores--Redwood cores placed between door plates increase the delay times for thermal cutting tools by a factor of between 3.5 and 4 times that of an air void. The penetration resistance to explosives or tool attacks of a door upgraded with redwood core has not been evaluated. Other types of wood might produce the same results as redwood does against thermal tools; however, no other types have been tested.

Locks and frames--Pry bars can be used to attack the door's lock and frame area to force the frame strike away from the lock bolt. A forced separation of 1/2 to 3/4 inch is usually enough to pry open a door. A method has been devised to prevent easy access to the lock and frame area. A 10-gage sheet steel strip can be either welded or bolted to the door (see figure). This strip should be the same height as the door and at least 2 inches wide, with a 1-inch overlap onto the adjacent door frame. In addition, the frame should be grouted with concrete mix at least 18 inches above the frame strike location. Holes can be cut in the door frame to allow grouting of both sides. The holes could then be patched with a cover plate, which is welded or screwed into place. A high-security lock could also be installed on exterior pedestrian doors since lock defeat is one of the quickest and quietest means of gaining entry to a protected area.

guidance SECURITY/4 Zone 3

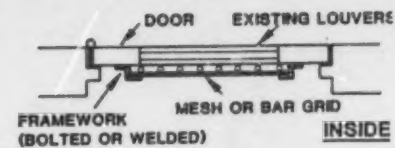


PRY STRIP

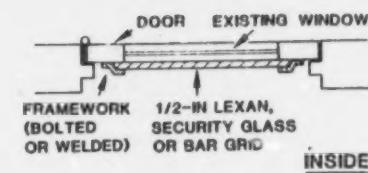
Hinges--These can be compromised in approximately 1 minute by removing the pins or by cutting the hinge knuckles. Welding the pin top to the hinge will extend penetration times if only hand tools are used; however, if the hinge knuckles are cut with a saw or portable cutting torch, the penetration time is still about 1 minute. Upgraded hinges with a stud-in-hole feature (see next figure) are commercially available. This type of hinge extends penetration time. Another method to prevent hinge-side door removal is to use a Z-strip made from 10-gage steel, which is bolted or welded to the rear door face (see the figures "Hinge and Doorface Hardening Options"). This strip is formed so that if the door hinges are removed and an attempt is made to pry the door from its frame, one leg of the Z-strip will come in contact with either the inner frame surface or the rear door stop surface (see the figures). Once the Z-strip contacts the door frame, adversaries must use excessive force and large pry bars to remove the door. This attack requires about 2 minutes. Full-length piano-type hinges for steel pedestrian doors are available commercially and might extend penetration times, but they have not yet been evaluated.

Louvers and glazing. Louver and glazing material use should be minimized for exterior doors since these assemblies can be easily penetrated with a sledgehammer or fire axe. Removal of all door louvers and glazing or a reduction in size (less than crawl-through) is recommended. Possible upgrades include adding a screen or bar grid inside the louver or glazing (see the next figure). For additional information on screens and bar grids, see "Utility Ports."

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DOOR LOUVER UPGRADE



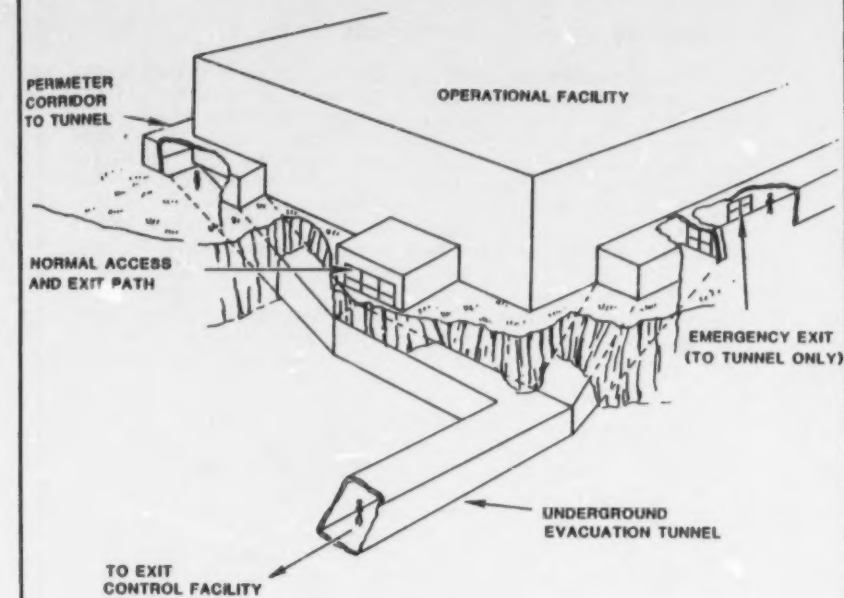
DOOR WINDOW UPGRADE

Multiple deadbolts. Replacement of a single, conventional deadbolt with a high-security, multiple dead-bolt system would virtually eliminate prying attacks.

Air locks. Explosive attacks on industrial doors present different design problems. For practical purposes, air locks or a series of doors for either pedestrians or vehicles can be used for upgrading existing facilities. In an area for which a limited number of personnel might use an emergency exit, a one-way turnstile could be used inside the exterior door to prevent rapid penetration by an adversary.

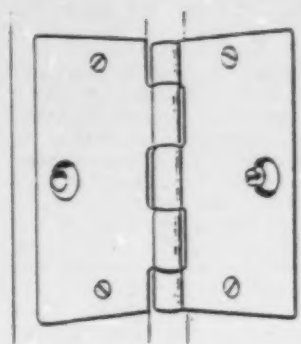
Exit tunnels. The insider breakout threat through emergency exits or normal portals can be controlled using hardened exit tunnels that lead to hardened, safe holding areas.

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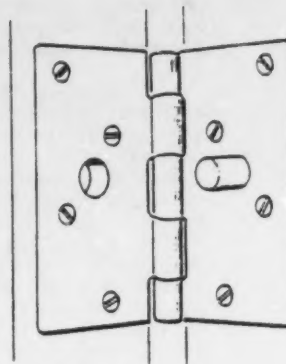


EMERGENCY EXIT TUNNELS.

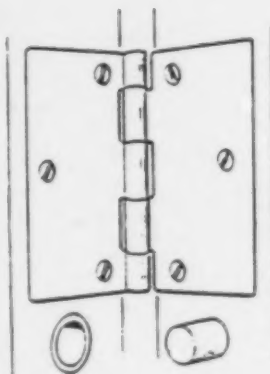
guidance SECURITY/4 Zone 3



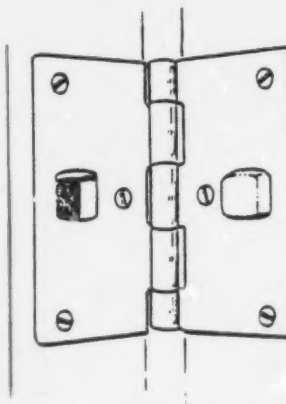
A) Use of special "stud-end" wood screw that engages in a matching hole when door is closed.



B) Addition of a metal dowel-pin and socket to the existing hinge.



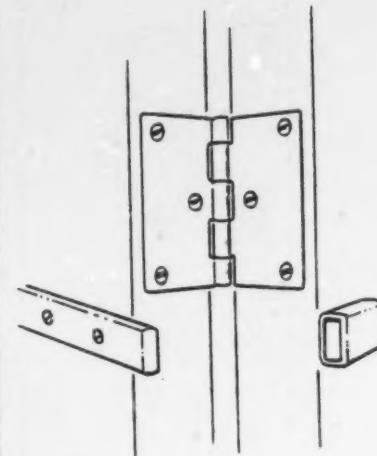
C) Installation of a metal dowel-pin in the door and reinforcing metal cup in the door frame.



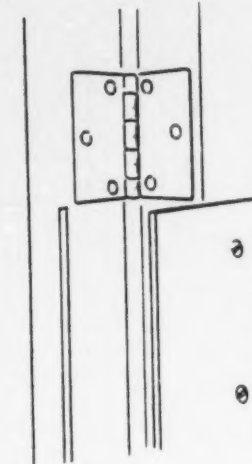
D) Hinge with lug and matching socket formed into hinge at factory.

HINGE AND DOOR INTERFACE HARDENING OPTIONS FOR PERSONNEL DOORS.
(37) 13.1-88

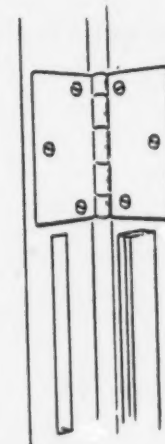
guidance SECURITY/4 Zone 3



E) Add-on, surface mounted pin and socket.



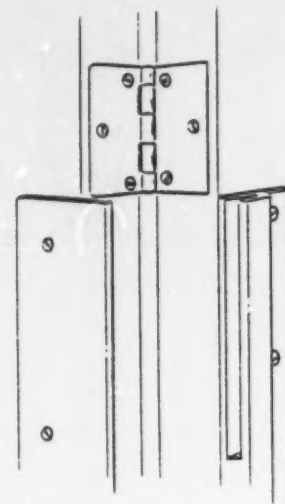
F) Metal spine installed in door edge and matching groove in door frame.



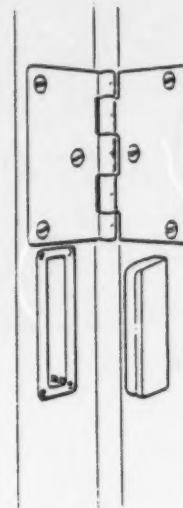
G) Surface mounted metal spline attached to back of door with matching groove in door frame.

HINGE AND DOOR INTERFACE HARDENING OPTIONS FOR PERSONNEL DOORS (CONT'D).
(37) 13.1-89

guidance SECURITY/4 Zone 3



H) Surface mounted metal "spline" and receptacle.



I) Metal lug and receptacle system.

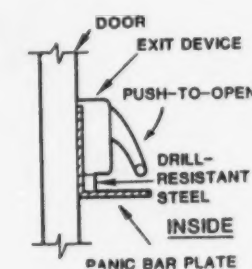
HINGE AND DOOR INTERFACE HARDENING OPTIONS FOR PERSONNEL DOORS (CONT'D).
(37) 13.1-90

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Panic bars. Most exterior doors are equipped with "panic" hardware that allows rapid exit in case of emergency. However, this safety equipment also makes a door more vulnerable to defeat. Upgrades are needed to lessen this vulnerability.

A hardened steel plate mounted inside a door can extend penetration delay time slightly; however, drilling and wire manipulation of the panic bar can still allow penetration in about 1 minute. One possible method of upgrading a panic-bar-equipped door is to use a bent metal plate with a drill-resistant steel section fastened to it (see the next figure). The plate prevents chiseling and wire hooking of the panic bar, whereas the drill-resistant section extends penetration time considerably if the area between the panic bar and the plate's horizontal leg is attacked. If any other place on the door is selected for drilling, wire manipulation becomes considerably harder since the wire hook may hit the horizontal leg when pulled.

Tests for prying attacks on doors equipped with panic hardware indicate that mortise-type panic hardware resists penetration much longer than rim-type hardware. When a door is pried, the rim-type panic bar attachment screws can either shear or pull out of the rear door face.



PANIC BAR UPGRADE.

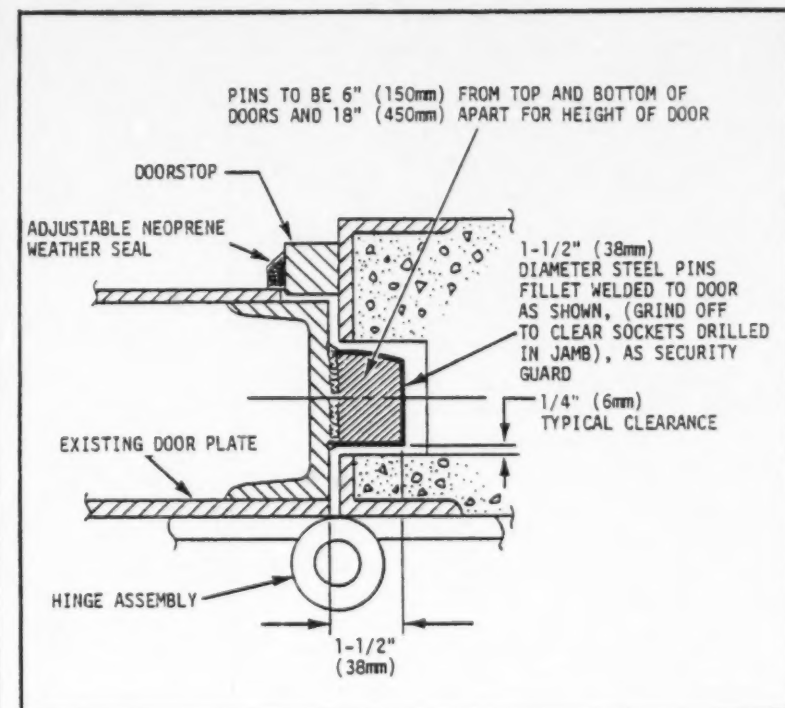
guidance SECURITY/4 Zone 3**GENERAL HARDENING CONSIDERATIONS FOR DOORS (37) 13.1-67**

Door type	Vulnerable area	Technique
Large horizontal sliding	Operating system	Protect electrical system and manual override
	Hanger/roller assembly	Protect from reversal of installation
	Door bottom	Secure firmly to prevent prying
Roll-up	Entirety	Add other barriers (i.e., grill wire) or horizontal sliding doors
Hinged door	Hinge	Should not be removable from door or frame
	Can bolt	Should be at least 1 in. (25 mm) in diameter
	Hinge side of door	Equip with interlocking mechanism to prevent opening if hinges removed
Solid wood, laminated wood, substantial hollow metal	Surface	Clad attack side of door with heavy gage metal or steel plate, 12-gage (2.7 mm) or greater (prefer 0.15 in. [4 mm]) Wrap metal around sides to prevent peeling
General	Frames	Make from steel 1 gage heavier than the door
General	Frame jamb and head	Add grouting or other reinforcement to wall to prevent jamb from being spread
General	Hinge pin	Weld in place
General	Frames	Add steel armor strips or grouting to prevent bullet penetration
General	Lock	Use high-security locks available on the market Use multipoint locking (i.e., more than one lock) Avoid exposing lock hardware Flush mount lock to avoid access to external hardware
General	Padlock	Replace padlocks with recessed high-security cylinder locks

guidance SECURITY/4 Zone 3**DOOR SURFACE HARDENING OPTIONS (37) 13.1-69**

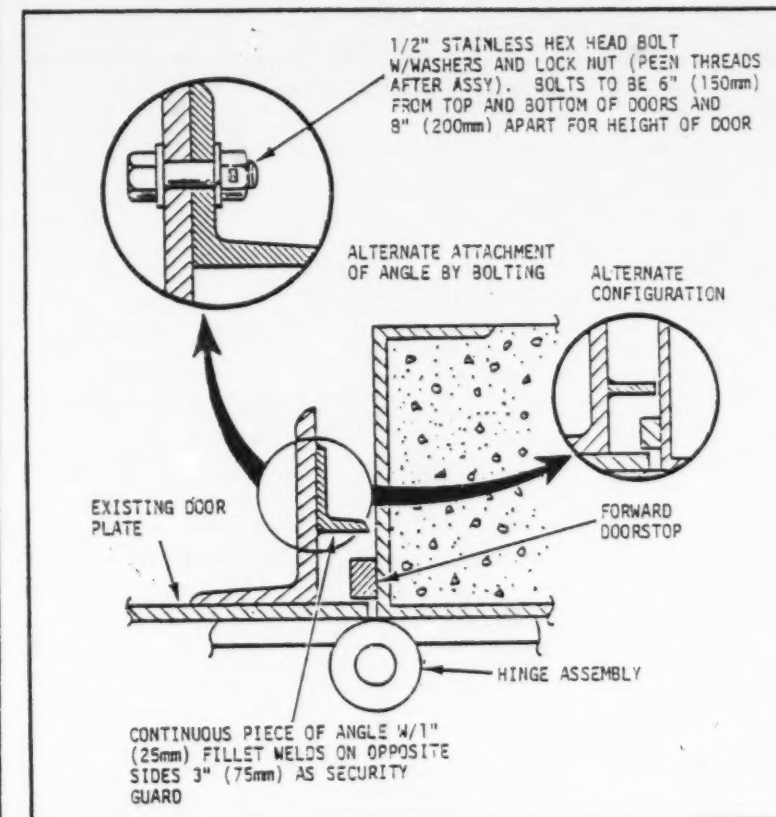
Door Construction	penetration time (minutes)
Steel Plywood	
2 layers 10 gauge (3.4mm) hot roll steel/1 layer 3/4 in (19mm) exterior plywood	6
3 layers 10 gauge (3.4mm) hot roll steel/2 layers 3/4 in (19mm) exterior plywood	12
2 layers 9 gauge (3.8mm) ASTM 607 HS, low alloy steel/1 layer 3/4 in (19mm) exterior plywood	14
2 layers 9 gauge (3.8mm) ASTM 607 HS, low alloy steel/1 layer 3/4 in (19mm) exterior plywood/2 layers of 90 lb (41kg) gravel finish roof paper	20
9 layers 3/4 in (19mm) steel, 3 in (75mm) redwood, 0.036 in (0.9mm) steel	27
Steel redwood	
3 layers 3/8 in (9mm) steel, 3 in (75mm) redwood, 0.036 in (0.9mm) steel	6
Steel Polycarbonate	
3 layers [0.88 in (22mm) thick]: 1/4 in (6mm) type 304 stainless steel plate, 1/2 in (13mm) polycarbonate, 10 gauge (3.4mm) ASTM 607 steel sheet	10
5 layers [1.4 in (22mm) thick]: 3 sheets of 10 gauge (3.4mm) ASTM 607 steel, 2 sheets of 1/2 in (13mm) plexiglass	17
5 layers: 3 sheets of 10 gauge (3.4mm) ASTM 607 steel, 2 sheets of 102 in (13mm) lexan	17
Reinforced Concrete	
Blast hardened type doors	up to 60 or more

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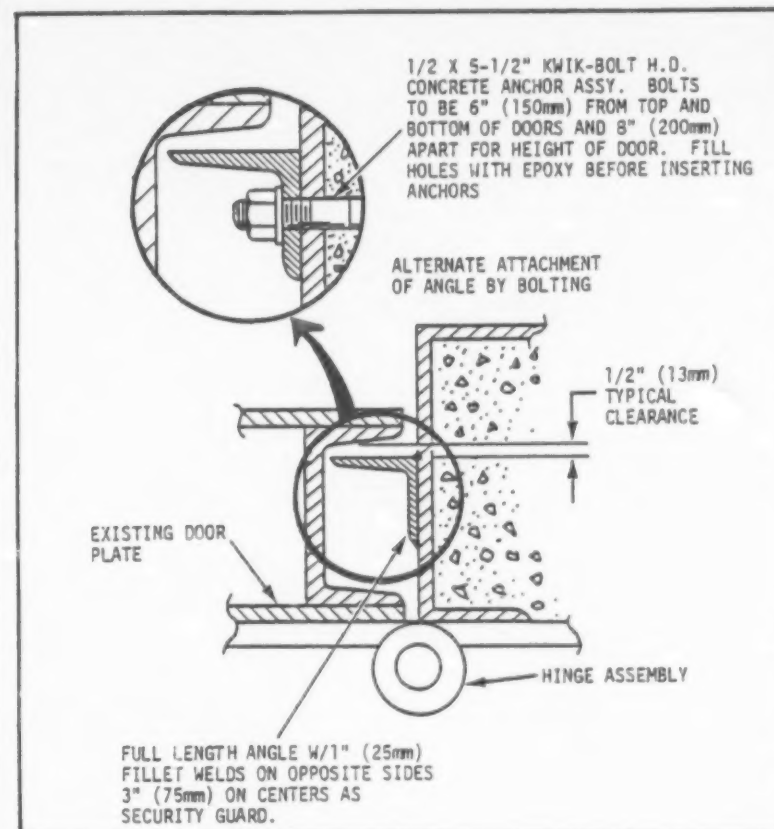
SECURITY PLAN FOR DOORS USING A PIN-IN-SOCKET TECHNIQUE. (37) 13.1-43

guidance SECURITY/4 Zone 3



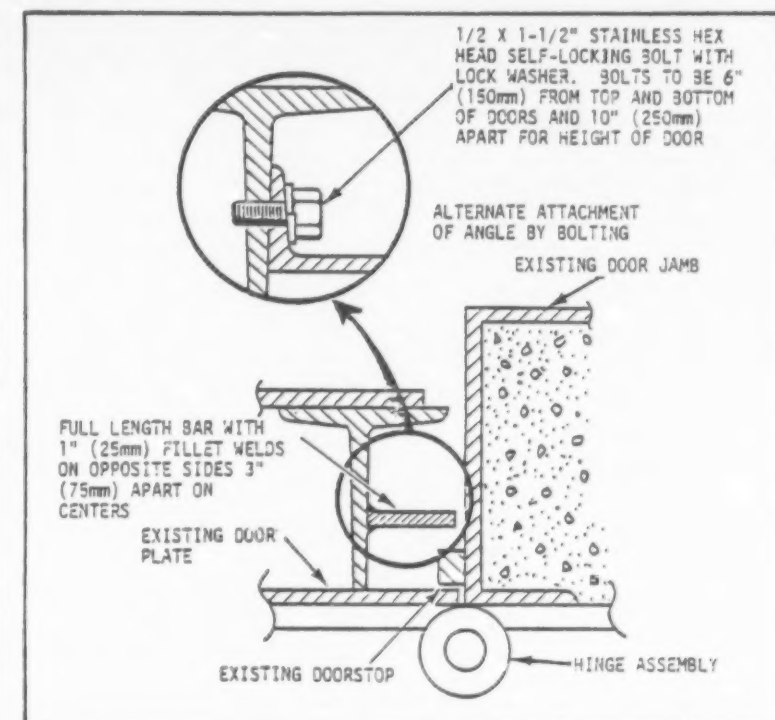
TYPICAL HARDENING PLAN FOR DOORS USING A FORWARD DOORSTEP WITH ANGLE. (37) 13.1-144

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SECURITY PLAN FOR HARDENING TYPICAL THICK DOORS USING AN ANGLE STOP (37) 13.1-145

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SECURITY PLAN ALTERNATIVE FOR HARDENING TYPICAL THICK DOORS USING AN ANGLE STOP. (37) 13.1-146

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Vehicle access doors--Many previous considerations on vulnerability, attack modes, hardware, and upgrading of pedestrian doors also pertain to vehicle access doors. This is especially true when construction of the doors is essentially identical and the main difference is size. A vehicle doorway is one of the largest structural openings that need protection. Corrugated roll-up and hollow-steel panel doors are found throughout industrial and Government buildings. Standard industrial doors are available in swinging, sliding, rolling, telescoping, bifolding, and biparting designs. They are used primarily to minimize the effects of weather, noise, and pollutants or to provide privacy. Many vehicle access doors seriously degrade the structure's barrier value because they have not been designed to resist forcible entry. Entry can be achieved by (1) cutting a human-sized opening in the door face, (2) using a vehicle to force a human-size opening, (3) using a vehicle to ram the door at high speed to permit entry of the vehicle itself or, if the vehicle is damaged, to open the doorway for entry by another vehicle, or (4) using explosives to produce either a small crawl-through opening or a large opening for a vehicle. Unfortunately, no published specifications, Federal construction guidelines, or security manuals provide standards for increasing penetration delay against the threat of a determined adversary using simple tools or against forcible entry by ramming with a vehicle. This section discusses access doors used for entry by vehicles such as trucks, automobiles, and commercial vans.

Although there are usually fewer vehicle doors than pedestrian doors at a facility, most vehicle doorways can be penetrated easily in a very short time by ramming the door with a vehicle. Design limits imposed by the door's function and hardware make it an inherently weak link in a barrier system and make it difficult to barricade. The corrugated steel roll-up door is widely used; however, this type of door affords very little resistance to forcible entry. Specifications only require great enough curtain stiffness to withstand a wind pressure of 20 pounds per square inch. Careful consideration should be given to eliminating vehicle doorways whenever possible.

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Vulnerability. Both steel roll-up and steel panel doors offer very little resistance to explosive attack. Delay is governed by the time required to set up the explosives, retreat a safe distance, and return and crawl through the opening. The calculated delay is 1 minute. Other types of doors are made like pedestrian and igloo doors and provide a resistance to hand-tool cutting attack similar to that for such doors. Refer to discussions of igloo and pedestrian doors in this section. Tests to establish baseline penetration times for hand attack modes on a typical vehicle access roll-up door were conducted on a 12-foot-square door constructed of 18-gage galvanized steel with interlocking slats. The extra-heavy-duty slat with a high, flat crown resists deflection. Attack tools used in these tests were representative of the abrasive, thermal, and forcing tools normally used for forcible entry.

PENETRATION TEST RESULTS FOR CORRUGATED ROLL-UP DOORS FOR VEHICLE DOORWAYS

Tool	Penetration time (min)
Rescue	0.50
Demolition saw	0.93
Demolition saw	1.04
Oxygen lance	1.41
Oxyacetylene torch	1.69
Oxyacetylene torch	2.52
Fire axe and pry bar	3.13
PAK-KUT torch	5.41
Saber saw	9.28

Upgrading vehicle access doors. When vehicle access doors cannot be eliminated, security considerations involve more than just enhancing the door design by increasing its ability to absorb energy. The total door installation, including fittings, locks, and hardware, must be considered. The siting of the doorway, its orientation, and its function are also important factors.

Hand tool attack. Doorways can be designed with multiple doors to form airlocks for controlling vehicle and personnel entry. Multiple doors could be used to greatly increase penetration time. Subsequent doors in the series would have to be attacked with tools lifted through the opening in each door and used in the confined space between the doors.

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Combinations of doors can also be used to increase penetration time. A double swing door placed adjacent to and inside a roll-up door would complicate penetration by requiring the repetitive use of hand, power, and thermal tools. Steel plate doors, which can be used to replace corrugated roll-up doors, offer more penetration resistance to surface attack with cutting thermal tools; however, the hinges, lock, and frame must provide the same resistance. Replacing corrugated steel roll-up doors with steel plate doors similar to igloo doors is a feasible upgrade.

These upgrades may also be effective against ramming attacks. Again, the upgrade does not need to exceed the penetration resistance of the host structure and, conversely, unless the doorway can be upgraded, it may not be cost-effective to upgrade building structure.

Vehicle ramming attack (on-grade vehicle access doors). Siting considerations are often a more practical upgrade option than the addition of steel and armor to the door itself. High-energy vehicle impact can be prevented by imposing controls on vehicle approach speeds. Long straight approaches can be avoided in favor of right-angle turns or sharp curves. Also, vehicles can be parked in the driveway in front of the door. Reducing the impact velocity is an effective upgrade because impact energy is a function of the square of the speed of the vehicle. Crash beams can be installed to protect the door from ramming by forcing vehicles to stop before entry. Crash beams are simple in principle and can be custom-designed for a variety of installations. A crash beam is not effective against hand-to-attack, but it may prevent the close approach of a vehicle and thus force the transport of attack tools by hand over longer distances, increasing total penetration time. Loading docks also protect vehicle access doors from ramming. Moreover, vehicle access doors can be protected against ramming by using thresholds in the form of trenches, slots, or holes that engage deadbolt spikes.

Several concepts that have been tested for other applications could be used to upgrade vehicle access doors. Rubber tires could be installed directly behind an outer vehicle access door. Also, a rubber door clad with sheet metal could be used to resist impact penetration by a vehicle. A redwood core could be added to a panel door to increase thermal tool penetration delay. The increased weight also requires installation of heavier hardware, which also improves resistance to hand tools and vehicles. A redwood core does not delay

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penetration attacks with explosives. A door could be designed of alternately laid steel channels welded together and clad in thin sheet metal to provide greater penetration resistance. Other concepts, such as removable ramps across ditches or a road span that is lowered and raised on a hydraulic lift (drawbridges) could be developed for special cases.

Igloo doors (see also S88--"Survivability")--Igloo door designs vary in size, shape, and function. Door thickness may vary from a single sheet 1/4 inch thick to a 6-inch double-faced design, depending on the type of storage and the site. These doors are frequently secured with a padlock and hasps. Igloo designs have evolved from World War II munitions storage depot structures, in which personnel safety and blast protection were major considerations. In the years since World War II, upgrading these doors has consisted mainly of using improved locking mechanisms and welded hinge pins.

An attack using several pounds of explosives will penetrate most igloo doors in less than 1.5 minutes. An attack on door hardware decreases penetration time to about 0.5 minute. Penetration through a human-sized hole cut with a thermal tool can circumvent a door alarm that senses door movement, and usually requires less than 5 minutes to perform. To insure balanced hardness for a door upgrade, attention must be given not only to door cross sectional construction but also to the hinges, locks, and locking systems.

Attack modes

Hinges. These vary with door size, but are usually externally mounted with deadbolts. If the physical mass of the door can be handled, the hinge pins or the hinge itself can be removed and the door can be swung open unless items such as hidden deadbolts or Z-strips are used.

Padlocks. These are often the "weak link" in an igloo door; they are easier to defeat than embedded door locks because they are more accessible. Most padlocks can be cut with boltcutters; thermal tools are equally effective. Picking a padlock requires an unknown amount of time since it depends on the type and physical condition of the lock. If shimming the lock is possible, entry time is minimal.

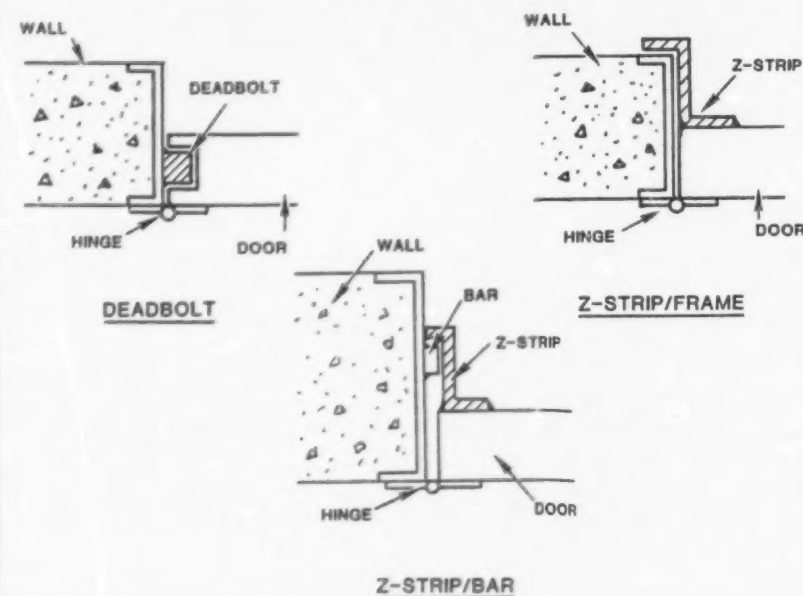
Hasps. Most igloo doors have two equally large hasps that, in some cases, can be several feet long but have small cross sections. A cutting torch can be used to sever a hasp quickly. High security hasps with locks are available; however, because the hasp is accessible, penetration using thermal tools takes less than 1 minute.

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Improved design concepts

Redwood cores and nails. The body of an igloo door can be upgraded by inserting a redwood core into the space between the double walls. This upgrade is basically designed to resist thermal tools. Power-driven stud nails can be used to fasten the redwood between the double-walled steel door. Thermal cutting tools become inefficient against the cross section of a door altered this way; it takes approximately four to five times longer to penetrate this cross section than to penetrate a hollow door section. Preliminary explosives tests show very little difference in penetration time when the same amount of explosives is used on a wood-filled and hollow doors.

Passive deadbolts. Hinge vulnerability can be decreased by providing a bar bolt to hold the door within its frame despite hinge removal. If the door cannot be modified to accept this type of deadbolt, a heavy Z-strip can be added to the rear face to overlap the door frame or a vertical bar can be welded to the frame.



HINGE UPGRADES FOR IGLOO DOORS.

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Locks and locking systems. Replacing padlocks with recessed high-security cylinder locks and improved locking mechanisms or multiple deadbolts are methods of increasing the penetration delay time afforded by an igloo door. However, if padlock replacement is not feasible, high-security padlocks and hasps would provide a minimum upgrade.

Concrete blocks. Although not a new idea, concrete blocks are a very effective method of sealing off an igloo entrance. A large concrete block could be placed in front of igloo doors by a forklift that is then removed from the area. The block is either placed over a protruding, upright I-beam inserted into a concrete pad in front of the doors or is contained between upright posts. These configurations provide a very effective "padlock."

guidance SECURITY/4 Zone 3**4. Windows**

Windows present only minimal penetration delay to adversaries and require enhancement to provide significant resistance. The location of the window affects the upgrading required. Windows should follow the balanced design principle so that they will not be the weak link in a barrier system. This section describes frames, glazing materials, and protective coverings, as well as other suggestions for improving window penetration delay times.

WINDOWS, CONVENTIONAL CONSTRUCTION (37) 13.1-92

Window construction	Penetration time (minutes)
All standard type windows, metal security frame and sash, with one of the following type glazing:	
0.09-in. (2.5-mm) annealed glass, single strength (Federal Specification DD-G-451, Latest Edition)	
0.12-in. (3-mm) annealed glass, double strength (Federal Specification DD-G-451, Latest Edition)	
1/4-in. (6-mm) tempered glass (DD-G-1403, Latest Edition)	
1/4-in. (6-mm) laminated "security glass"	
1/4-in. (6-mm) wire glass	<1
1/2-in. (13-mm) wire glass	
1/4-in. (6-mm) polycarbonate*	
1/2-in. (13-mm) polycarbonate	
1-in. (25-mm) polycarbonate	
1/4-in. (6-mm) acrylic	
1-in. (25-mm) acrylic	
All standard type windows, as described above, plus standard military steel bars and gratings	<2
1/2-in. (13-mm) steel rod covering over 1/8-in. (3-mm) glass, larger than human-sized panes	0.3
Mesh covering over 1/8-in. (3-mm) glass window, smaller than human-sized panes, coverings fastened with rivets, standard sash	0.5

*NOTE: The thickness of polycarbonate or acrylic glazing does not significantly alter penetration time, at least in 1/4- to 1-in. (6- to 25-mm) ranges. (37) 13.1-92

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Frames--Frames and sashes are classified as fixed or operable, casement, awning, sliding, and so forth. The size of the glazed opening varies according to the sash dimensions and the muntin-mullion configuration. These two elements of the frame may be the most vulnerable parts of a window, especially when the glazing material is laminated security or armor type.

The strength and weight of the window's frame material vary widely with class of window and manufacturer. Some manufacturers make a "security sash"; however, this term can be misleading, since the frame material is not hardened. When windows are installed in doors, the muntins have proven to be weak. For example, a fire axe can be used to accomplish penetration in 13 seconds. However, several special window frames are manufactured containing concealed materials that resist cutting tools. The frames and sashes are made of stainless steel, steel, aluminum, and wood; aluminum and steel are the most common materials. If a window is operable, the locking mechanism may constitute a weak link, and if forced, this window can be opened.

The position and operation of the window's locking mechanism vary with type and manufacturer. The mechanism should be located so that it is not readily accessible from the outside. The installation of more substantial locking devices or fixed windows could be considered as possible upgrade options.

Frame attachment to the structure can be improved by using additional or heavier fasteners or by welding the frame fin, but these techniques may not affect the delay time unless additional upgrades are made to the glazing materials and protective coverings.

Glazing materials--Glass and plastics are the most commonly used types of glazing materials. Glazing is generally the weak link in window penetration time. The best possibilities for penetration-resistant glazing appear to be so-called "security glass" or "transparent armor." Extensive tests have been run on such materials to determine their resistance to ballistic penetration; however, very little data are available on which to base an estimate of penetration time against human-sized openings. In general, glazing material is not necessarily attack-resistant. (37) 13.1-94

Glass--Glazing materials include standard, tempered, wire, and laminated glass. These types of glass provide a barrier to the elements, but not significant delay times.

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Standard glass. These materials are highly frangible. Penetration by hand tools generally requires less than 20 seconds. When a higher level of penetration resistance is required, thick security glass can be used. In addition, standard glazing materials are often upgraded with a protective grill of expanded steel mesh or other forms of metal grills.

Tempered glass. This is formed by the reheating and sudden cooling of a base glass. Although tempering greatly increases the glass' mechanical strength and thermal stress, it can still be easily broken with moderate force. It can be shattered into gravel-sized pieces by hand tools (impact) in less than 10 seconds, and complete penetration can be done in approximately 17 seconds.

Wire glass. Wire glass is mainly used in fire doors and fire windows as required by the National Bureau of Fire Underwriters (NBFU) codes; most types of wire glass are Underwriters Laboratories (UL) listed for this purpose. The 1/4-inch-thick material is made with diamond, square, or hexagonal wire patterns; the minimum wire size is No. 85 ASW gage. Nontransparent wire glass can also be used as a glazing material. Penetration of wire glass can be achieved by hand tools in approximately 20 seconds.

Laminated glass. This is manufactured as a "safety and security glass"; however, not all types of laminated glass are recommended by the manufacturers for use in security areas. Laminated glass is composed of two or more panes of annealed float, sheet, or plate glass bonded to a layer or layers of polyvinyl butyral plastic and ranges in thickness from 0.050 to 0.090 inch. The thickness of the composites range from 9/32 to 13/16 inch, depending on the manufacturer. Safety glass 1/4 inch thick can be penetrated in 30 seconds while 9/16-inch-thick security glass requires 1-1/2 minutes of work with a sledgehammer and fire axe to provide a crawl-through hole. Security glass is not transparent armor. It is simply more resistant to forcible penetration than standard glass.

Plastics--Transparent plastics (acrylics and polycarbonates) can be used as substitutes for most glass; however, some are combustible and their use is restricted by fire codes. Acrylic plastics (Lucite and Plexiglas) up to 1 inch thick can be easily broken with either a fire axe or sledgehammer in less than 10 seconds, with penetration in 17 seconds. Surprisingly, however, both acrylics are highly resistant to thermal tool penetration attacks. The impact

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resistance of polycarbonates, on the other hand, approaches the same performance level as that of "bullet-resistant glass." Tests show that 1/2-inch-thick Lexan resists both fire axe and sledgehammer penetration for up to 2 minutes. Thermal tool attacks require about 1 minute, but combustion and toxic gases also result. Both acrylic and polycarbonate plastic panels up to 1 inch thick can be easily cut with a demolition saw in less than 1 minute.

Protection--A window's penetration resistance can be increased by installing protective coverings, such as grills, bars, expanded-metal mesh, or screens.

As noted above, in situations requiring high security, windows should not be used. If they are necessary, they should be smaller than human-passable size, 96 square inches (0.06 square meters), and openings (frames) should be heavily reinforced with steel plate since they provide an avenue for enlargement and wall penetration. Other important factors to consider in choosing among window designs include the following.

Windows. These comprise a system with at least four components: frame, sash, glazing, lock, and in some cases, hinges. Each component should provide the same degree of penetration resistance.

Frames. These should be securely fastened or cemented to the surrounding structure to prevent easy separation and penetration at the interface.

Sashes. These should not be removable from the frame (as is the case with many horizontal sliding types).

Steel frames, sashes, and muntin-mullions. These can improve penetration resistance somewhat. Use of steel in frames, sashes, and muntin-mullions forces an intruder to use more sophisticated tools, but does not otherwise increase penetration time against a well equipped intruder by more than 1 or 2 minutes--and only if panes are kept well below the roughly 10 x 10 inch (250 x 250 millimeter) opening required for human entry, so that multiple cuts are necessary. As discussed previously, if possible, windows (observation ports) should be kept at less than human-passable total size (96 square inches [0.06 square meters]). However, they can provide a convenient opening for the start of wall penetration cuts. Therefore, frames and the surrounding wall interface should be heavily reinforced. (37) 13.1-95

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Glazing. Should not be easily removable from the exterior.

Fixed windows. These generally provide better penetration resistance because the locking component and hinging arrangement are eliminated.

Glazing material for fixed windows. This material can be installed directly into the window frame or a sash; however, panes of glazing material preferably should be less than 96 square inches (0.06 square meters) in area.

Ventilating system. A separate ventilating system is generally preferable to opening windows.

Locks (latches). These should be located so that they are not easily accessible by breaking out adjacent glazing and/or using a length of heavy wire. (37) 13.1-91

Bars and grills. Data indicate that bars and grills only increase penetration times by 1 to 2 minutes. The table below shows, however, that penetration time is directly related to the diameter and spacing of bars, and if, for example, No. 8 (1-inch [25-millimeter]) bars, spaced 3 inches (75 millimeters) apart (both vertically and horizontally) are used to form a grill, a penetration time of about 8 minutes can be achieved. A double grill of that type should increase penetration time to over 15 minutes. More grill layers would increase the penetration time proportionally. When bars, screens, or grills are used as penetration delay devices, the method of anchoring them to the wall is critical, since it may be easier to tear or pry them loose than to cut them. A suitable anchoring design should be used, although no test data are available that show what may be optimal at this time. (37) 13.1-95

Mesh. Expanded steel mesh (diamond pattern) enhancements (nominally 9 gage) can be considered for a slight improvement to delay time; however, these enhancements can be penetrated with hand tools in less than 30 seconds. An improvement to this mesh concept would be to use expanded bank vault mesh with a 3- by 8-inch diamond pattern (3/8 inch thick), weighing 6 pounds per square foot. This mesh could be welded to a frame or to the structure, thus forcing the adversary to use tools of a higher category in addition to providing longer (greater than 1 minute) delay times.

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Screens. The standard screen of stainless steel, bronze, or galvanized steel can be readily cut by hand tools in less than 30 seconds and offers little appreciable delay to penetration. However, if 3/4-inch quarry sieve screens are used, hand tools become ineffective, and penetration with a demolition saw requires 1-1/2 minutes. For complete information on grills, bars, mesh, and screens, see the next section, "Utility Openings."

Conclusions--Conventional windows cannot provide penetration times greater than about 2 minutes; the usual penetration time is .5 minute or less. Therefore, as a general principle, windows should be omitted from a high security facility design, unless there is an overriding operational requirement for them. For example, such a requirement could be to have an observation port for security or safety, or for essential business transactions. Even when observation is required, the possibility of substituting a closed circuit television system for windows should receive consideration. When observation ports are essential, they should be kept as small as possible, preferably less than the area (96 square inches [0.06 square meters]) required for human-passable openings. (37) 13.1-86

Standard windows are barriers that afford little penetration delay time without enhancement because most can be penetrated with hand tools in less than 30 seconds. Windows can provide a stealthy path into a facility and are often considered the "weak link" in the total building barrier system. The degree of improvement should be dictated by the balanced design concept. With the proper choice of enhancements (protective coverings, grills, mesh), different glazing material, or methods of frame attachment, the delay time of windows can approach that of doors or even walls for some threats.

When protective coverings are used, care must be taken to insure that their attachments to the structure do not provide a lower penetration delay. Without enhancement, the choice of glazing material may not greatly increase penetration time unless thick security glass or transparent armor is chosen.

An option to consider in future designs for new buildings is smaller than human-sized windows. Also, windows could be removed from existing structures; this would allow the original window openings to be upgraded to the same penetration delay as the adjoining wall.

guidance SECURITY/4 Zone 3**5. Utility openings (37) 13.1-97**

In conventional building designs, utility openings, manholes, tunnels, air-conditioning ducts, filters, or equipment access panels can provide intruders an attractive entrance or exit route with no significant delay. Such openings must be eliminated, or delay times significantly increased, if consistent physical security is to be achieved for the overall structure. The following subsections briefly describe typical utility openings and the factors and issues that require special consideration in determining and enhancing delay times.

Conventional construction--This subsection describes conventional construction methods for electrical system conduits, mechanical system conduits for air-conditioning, heating, and ventilating systems, roof-mounted equipment, filter banks, manholes, and other openings.

Electrical and mechanical conduits. These conduits consist of tunnels, pipe chases, and sleeves and trays as well as ducts, gravity vents, and exhaust ducts for air-conditioning, heating and ventilating systems.

Tunnels for electrical and mechanical utilities between buildings are seldom well protected. They are typically installed in very large facilities, can be 8 feet (2400 millimeters) or larger in diameter, and are made of reinforced concrete. They may have lift-off covers or access manholes with no locking devices or interior barriers. The utilities often enter the buildings from such tunnels through a frangible (knockout) panel or through walls or ports that can be penetrated easily because of their construction. Maintenance accessibility, rather than security, has been the primary consideration in some tunnels. Such tunnels can provide a potential, concealed path for an adversary and, thus, may be one of the weak links in the delay system.

Pipe chases are horizontal or vertical frame-in passageways. The sizes vary from 1 square foot (0.09 square meters) up to any desired size. They may be constructed of studs and gypsum board. Although they are often quite congested, they still allow space for maintenance work. In some facilities, vertical chases connect adjacent floors, thus providing unlimited access once an intruder is inside the chase system. Similarly, horizontal chases (walk-throughs) are confined spaces; however, there is usually no impedance to movement except that afforded by the internal equipment, piping, cables, and the entrance door(s), which usually use only standard lock sets. Some facilities may have interconnecting

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vertical and horizontal chase systems that open additional paths to an intruder. Maintenance personnel usually require routine or daily access, further increasing the difficulty of control. Entrances to or exit from overhead crawl spaces can also be gained from some chases. These chases must have barriers installed, since the path may otherwise be unlimited.

Sleeves are pipe penetrations 1 to 8 inches (25 to 200 millimeters) in diameter through walls, floors, or roofs, and are one pipe size larger than the penetrating pipe. These require packing for weatherproofing and fire rating. **Trays** are a sheet-metal, removable cover conduit, 3 square inches (0.002 square meters) or larger. Pipes carrying a liquid or gas present a natural deterrent if they must be cut for entry. Electrical cable trays may also present a natural deterrent; moreover, the free area is usually small, thereby presenting minimal risk. When needed, a closure plate or grid can be installed to close or reduce the opening. The cable tray's physical size will determine the degree of security enhancements required.

Ducts for air-conditioning, heating, and ventilation systems can be used for surreptitious entrance or exit. Ducts are round or square conduits of sheet metal or fiberglass that vary from 3 inches (75 millimeters) on a side, to diameters up to any required size (6 or 8 feet [1800 or 2400 millimeters] on a side). Ducts constructed of 28- through 14-gage (0.4- through 1.9-millimeters) sheet metal can readily be cut with hand tools and light power tools. These ducts do not present a major barrier to penetration. Penetration resistance is, however, sometimes incidentally improved using ducts of less than human-sized cross section, and by including the required appurtenances, turning vanes, dampers, pressure plates, or the final air distribution fixture. The standard specification for steel air ventilating grille units for detention units (ANSI/ASTM A 750-77) shows at least one secure design.

Gravity vents vary in size from 6 inches (150 millimeters) to 4 by 8 feet (1200 by 2400 millimeters). Since they terminate inside the building, gravity ventilation ducts, such as those used in storage igloos, provide direct entrance when attacked with cutting tools. A typical barrier now used in these ducts is a 3/8-inch (9-millimeter) thick perforated steel plate welded to an 18-inch (450-millimeter) diameter pipe.

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Exhaust ducts through roofs and walls are generally considered to be protected by the equipment used in conjunction with them. However, if the equipment is removed, the entrance is open. Because the duct work, dampers, and other parts are usually constructed of light sheet metal, penetration can be done using hand tools. Typical exhaust ducts range in size from 6 inches (150 millimeters) to 4 by 8 feet (1200 by 2400 millimeters).

Roof-mounted equipment--Units such as air supply fans, exhaust fans, gravity ventilators, and filter banks are usually either welded or bolted to an equipment curb, duct system, or foundation and can be removed with hand tools. Openings uncovered when equipment is removed can provide adversaries a path inside the facility. In many installations, removing only eight bolts and withdrawing the equipment can provide access.

Air supply and exhaust fans are usually made of steel sheet metal and vary in size from 12 square inches (0.007 square meters) up to 6 square feet (0.60 square meters).

Filter banks associated with heating, air-conditioning, ventilation, and other systems, can be a potential adversary path or point of sabotage. They are usually made of sheet metal and were construction with paper, plastic, or wire mesh elements, 12 by 24 inches (300 by 600 millimeters) in size, several elements wide. Some installations may require hardening for suitable penetration time. Filters can be installed in an exterior wall with the holding device exposed. Some filters require special attention because of the radiological or toxic materials that could be released or dispersed by a penetration attack involving thermal action, mechanical tampering, or other actions. Such safety issues must not be overlooked when attempting to increase intrusion delay time. Filters of this type may require installation in locked plenums without exterior access, or they may be constructed of materials with a high resistance to penetration.

Manholes--These are made of cast iron, concrete, fiberglass, or other material and, by definition, are large enough for human access, being 18 inches (450 millimeters) or larger in diameter. Unless properly protected, manholes for electrical power, communications, and sewers (storm and sanitary) offer an intruder a potential point of entry into a facility. The normal barrier is a cast iron or steel cover, which is occasionally bolted or held in place only by its weight. The estimated time of removal with hand tools is 20 seconds.

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Miscellaneous openings--Typical facility openings, such as skylights, roof-hatches, scuttles, elevator shafts, ash dumps, rubbish chutes, equipment penthouses, fire escapes, sidewalk grates, and roof access ladders, offer intruders access inside a building. Hardening for these potential penetrations should be considered when increasing delay times. The approach to upgrading these avenues will be dictated by the building elements involved, that is, by proper design of walls, roofs, floors, doors, and locking mechanisms.

Conventional utility opening penetration times--The table below summarizes the very little penetration time data available on specific types of utility openings. In addition, the table provides penetration data on conventional bar and grill security reinforcements specified in various military directives and standards. In general, these penetration times are less than 2 minutes. (37) 13.1-100

UTILITY OPENINGS, CONVENTIONAL CONSTRUCTION (37) 13.1-101

Construction type	Penetration time (minutes)
Sheet metal magazine vent with grill of rebar at bottom, 1/2-in. (13-mm) diameter, 6-in. (15-mm) on-center	1.6
36-in. (900-mm) diameter roof exhaust with 1/2-in. (13-mm) diameter security bars	1.1
Air-conditioning filter frame bank, 20 x 20 x 2 in. (500 x 500 x 50 mm) filter size with louvers	0.25
36-in. (900-mm) diameter duct, 18- to 24-gage (1.2 to 0.6-mm) sheet metal	0.65
Air-conditioning intake louvers, 22-gage (0.8-mm) sheet metal, hole size ranging from 10 x 20 in. (250 to 500 mm) to 36 x 48 in. (900 to 1200 mm) with 0.25-in. (6-mm) screen mesh	0.35

Hardening options--In most instances, utility openings must receive different consideration than windows and doors since they offer a variety of routes for the attacker. The next table summarizes estimated penetration times for specific hardening options discussed below. However, a note of caution must precede its use. Access by utility penetration often can

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be obtained by multiple routes. Therefore, a barrier may prove less effective than its estimated penetration time if it can be bypassed through a less time consuming assault path. For that reason, the qualitative guidelines in the following paragraphs will generally prove more useful than approximate quantitative values in estimating actual penetration times. This is true for both existing and upgraded utility openings designs. (37) 13.1-100

ATTACK RESISTANCE OF CONVENTION BAR-GRILL SECURITY REINFORCEMENT.
(37) 13.1-93

Option	Sources and Pertinent Excerpt	Materials Used	Penetration Time Seconds
1	DOD 5100.76M (June 1978). Page 3-2. Paragraph 3-200a. (5) (a). "Three-eighths inch (9mm) of larger hardened steel bars provided the vertical bars are not more than 4 inches (100mm) apart with horizontal bars welded to the vertical bars in such a manner that the openings do not exceed 32 square inches (0.02m ²).	3/8 in. (9mm) HARDENED BARS AISI 1050 heat treated to RC50	14.1
2	DOD 3100.76M (June 1978). Page 3-2. Paragraph 3-200a. (5) (a). "Three-eighths inch (9mm) or larger hardened steel bars provided the vertical bars are not more than 4 inches (100mm) apart with vertical bars welded in such a manner that the openings do not exceed 32 square inches (0.02m ²).	1/2 in. (13mm) HARDENED BARS AISI 1050 heat treated to RC50.	14.1
3	DIAM-50-3A (July 1980). Page 35. Figure 1. "One-half inch (13mm) diameter steel bars are used to form a grillwork that is to be imbedded into the masonry wall around the window opening. Vertically, the bars must be no more than 6 inches (150mm) apart; horizontally, no more than 3 inches (75mm) apart. Horizontally, the bars must be welded to each vertical bar in such a manner that the openings do not exceed 32 square inches (0.02m ²).	1/2 in. (13mm) MILD STEEL BARS ASTM A36.	14.1
4	DNA draft of "Nuclear Weapon Storage Facilities Handbook". 3.9 Window Lines 154-160. "Where security windows and frames are not used, the window opening must be covered by a rod and bar grill constructed of horizontal 1-1/4 inch (32mm) x 3/8 inch (9mm) flat steel bars spaced at 8 inch (200mm) maximum centers, and vertically 1/2 inch (13mm) diameter rods spaced 4 inches (100mm) on center either welded to or passing through the 1-1/4 inch (32mm) surface of the flat bars.	1/2 in. (13mm) MILD STEEL BARS ASTM A36. 3/8 in. x 1-1/4 in 9 x 32mm STEEL BARS ASTM A36	17.0
5	DNA draft of "Nuclear Weapon Storage Facilities Handbook". 3.9 Window Lines 163-165. "As an alternative to the above Grill (Specimen #4), a security screen equivalent to that described in DA OCE Drawing DEF 40-26-01 (Figure 3-23) may be used.	1/2 in. (13mm) NOMINAL STEEL PIPE ASTM A53 Type S Grade A 1/8 in x 1-1/2 in 3 x 38mm FLAT STEEL BARS ASTM A36.	22.1

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Option	Sources and Pertinent Excerpt	Materials Used	Penetration Time Seconds
6	Prison Standard Practice (selected by the Naval Civil Engineering Laboratory to be tested).	7/8 in (22mm) TOOL RESISTING DOUBLE-RIBBED BARS ASTM A62 1/8 in 2-1/4 in 19 x 57mm TOOL RESISTING FLAT BARS ASTM A829	27.9
7	Industry Security Practice (selected by the Naval Civil Engineering Laboratory to be tested).	7/8 in. (22mm) DOUBLE RIBBED ROUND BARS ASTM A36 1/8 in x 2-1/4 in (9 x 57mm) FLAT STEEL BARS ASTM A36	39.0
8	DIAM-30-3A (July 1976) "Physical Security Standards for Sensitive Compartmental Information Facilities". Section D - Air Vents and Ducts (3) (b) (1). "Hardened steel bars, 1/2 inch (13mm) diameter meeting a 600 or 650 Brinell rating mounted 6 inches (150mm) center vertically and horizontally and welded at all intersections".	1/2 in (13mm) HARDENED BARS AISI 1050 heat treated to RC50	12.8
9	Security Manager Handbook (December 1978). Pages 11-17 "Window openings will be fitted with 1/2 inch (13mm) bars (separated by no more than 6 inches (150mm) plus crossbars to prevent spreading.	1/2 in. (13mm) MILD STEEL BARS ASTM A36	19.5
10	Security Manager Handbook (December 1978). Pages 11-17 "No. 9 gauge (3.8mm) mesh (2 inch (50mm) square mesh fastened by bolts extending through the wall and secured on the inside of the window board."	STEEL WIRE MESH ASTM A497 WELDED 2 in. (50mm) SQUARE MESH 39 gauge (3.8mm) (W1.3 - ASTM A32)	28.0
11	This grid currently used by the Navy in structural applications, was selected by the Naval Civil Engineering Laboratory to be tested.	RIVETED STEEL GRATING MIL-8-130148 (SHIPS) TYPE A. Class 3. R-1R-1 1/2 (3/4x3/16 in.) steel	99.4
12	This grid, currently used by the Navy in structural applications, was selected by Naval Civil Engineering Lab to be tested.	GRID STRUT PANELS Fed Spec "RR-G-1602 Type II Para (3.3.1) 14 gauge (1.9mm) wt -6.1 lbs/sq. ft.	66.3

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Enhancing electrical and mechanical conduits

Tunnels, sewers, and manholes--Utility and communication tunnels and sewers (including storm sewers) originating outside a secure structure, but either connecting with it or passing close by, can provide a very convenient penetration route for an intruder. They are particularly vulnerable because it may be possible for intruders to work in them undetected for extended periods of time to cut through barriers. Conventional grills, gratings, locked manhole covers, and other barriers are probably worthwhile to discourage the less dedicated intruder, but they generally offer little increase in penetration time against a determined attack. The lock-on fastening device is usually the weak link. Multiple fixed grills with small interstices can have longer penetration times; however, they may not be practical in sewers where they can restrict fluid flow or increase the possibility of blockage by debris. It is extremely important to insure that structure walls, floors, or foundations accessible from such underground routes provide the required penetration time against attack. Furthermore, actual entry ports from the tunnels and sewers to the structure should, if possible, be constricted to make their expansion into a human-passable opening very difficult and time consuming.

An effective intrusion detection system that can detect preintrusion activities (for example, a seismic system to detect digging) is very important for high-risk facilities. When fluid flow capacity is a limiting factor in constricting tunnel/sewer openings, multiple small openings or a larger opening filled with 4- to 6-foot (1200- to 1800-millimeter) or longer lengths of steel pipe, welded together and anchored securely in place by a welded structure on the inside (secure side) of the structure can be used. If possible, such a barrier should be located with a sharp adjacent turn in the tunnel to further restrict the use of cutting tools. This arrangement can also be used for electrical lines, since maintenance personnel can have access to both sides of the impediment (constriction). That is, access is provided from both inside and outside the secure structure, and cables can be threaded through the relatively short constriction. Although no available test data give penetration times for this concept, 30 minutes or more are expected from barrier depths of 4 to 6 feet (1200 to 1800 millimeters). (37) 13.1-103

Pipe chases--These can be handled much like tunnels, sewers, and manholes. Conventional grills and locked access doors hinder maintenance activities and offer very limited penetration times unless massive doors and complex electrical

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locking systems are used. The constriction should consist of a series of hardened barriers (or fixed grills, as discussed below), each firmly embedded in or extended beyond the chase wall to prevent bypassing at the interface. Ideally, constrictions should be located at attack-hardened secure walls. The length of the constriction forces the intruder to attack and remove each barrier separately. Confined working space and the necessity for debris removal further adds to penetration time. Penetration times well over 30 minutes should be achievable using this method. Instead of solid barriers, a series of fixed grills may serve the purpose and can provide a penetration time of up to an hour--depending on spacing. Again, the long penetration time is derived from the length of the constriction, which greatly increases the problem of cutting and debris removal. It should also be noted that the pipes themselves will deter attempts to enlarge the opening by removal, if they carry liquids, gas, or steam. (37) 13.1-105

Sleeves and trays--These should penetrate security walls at a steep angle, so that the length of the opening will be great enough to prevent its use as a convenient entry for a saber saw or other cutting device. Holes should be angled upward and, to the extent practical, contain sharp turns to prevent easy introduction of hooks, cables, or explosives. They should be kept to the minimum possible dimensions. (37) 13.1-105

Enhancing air-conditioning, heating, and ventilation systems.

These systems consist of ducts, gravity vents, and exhaust vents.

Ducts--When used in air-conditioning, heating, and ventilation, ducts can provide a path for intruders. Ideally, to eliminate that possibility, duct dimensions should be kept to a cross section impassable to humans. However, airflow capacity requirements and cost may make such duct sizes impractical. In these instances, the discussion in this manual on window grills and gratings should be consulted. These techniques can be applied to ducts perhaps even more effectively due to confined working spaces and the possibility of using an in-depth barrier of multiple, widely spaced grills. Another possibility is to insert strategically placed honeycomb sections to restrict human passage. Although such sections will require care in design to avoid airflow and noise problems, they are feasible. The honeycomb material should be a grade steel reasonably resistant to cutting with hand and thermal tools (at least 1/16 inch [1.6 millimeters]); however, the penetration time will accrue mainly from the length of the honeycomb and the resultant necessity for

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multiple long cuts and debris removal in the relatively restricted space of the duct. Since duct walls are generally easy to cut through US 18- to 24-gage (1.2- to 0.6-millimeter) sheet steel, the honeycomb must be located strategically so that the intruder cannot bypass it by gaining entrance to the crawl space of "soft" ceilings. It may be necessary to reinforce the duct walls at some locations with high resistance materials such as 5-ply steel/plexiglass/steel/plexiglass/steel laminate. If practical, the honeycomb sections should be placed at sharp bends in the ducting. Depending on duct size, cost, and aerodynamics, an alternative approach could be to replace the single duct with a double or triple duct system at strategic points. As previously noted, including required appurtenances, turning vanes, dampers, pressure plates, or the final air distribution fixture may also add a few minutes to penetration time. Time can be increased by anchoring such fixtures securely and by using grills and bar gratings of a dimension and shape that force the use of large, unwieldy tools and thermal cutting equipment. (37) 13.1-107

Gravity vents. A key factor in hardening a vent is the depth (that is, volume of space) available for barrier installation. If the vent is simply an aperture in a wall or roof, the problem is similar to hardening a window with grills or bars. If possible, the vent should be sized impassable to humans. Penetrations through vents smaller than 96 square inches (0.06 square meters) (standard size of human-passable opening) require attacking the surrounding wall or roof to enlarge the vent. The vent itself may provide an advantage in such an attack; for example, it may eliminate the need to drill a hole for introducing tools. That advantage can be reduced by hardening the vent frame. If the vent must be kept at a size to allow human passage and if space exists behind it, the best approach to increase penetration time is to fill the opening with lengths of steel pipe welded into a honeycomb. Again, this causes the intruder to have to make cuts in depth, which increases cutting time, but also seriously interferes with the use of tools. In addition, it creates problems in removing debris and working in a confined space. Although not tested, barrier depths of 4 to 6 feet (1200 to 1800 millimeters) are estimated to generate penetration times of 30 minutes or more. An alternative approach is multiple, widely spaced grilled barriers in the shaft or duct leading from the vent. However, these approaches are only effective if the facility's mechanical layout is such that the intruder cannot cut a way out of the duct or shaft and gain access to the facility before the grilled barriers are reached. Even very small vents must be protected since they can be an easy route for introducing explosives; traps or bends at

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carefully selected locations can often prevent this. In conclusion, any vent, no matter how small, can provide a convenient entry for the blade of a tool used to breach the roof or wall through which the vent passes. Therefore, as a minimum, all vents should be hardened with massive steel collars at the structure interface. (37) 13.1-108

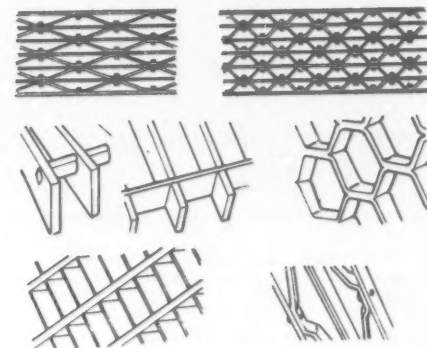
Exhaust vents. The previous discussion for gravity vents, ventilation ducts, and air distribution fixtures generally applies to exhaust vents. Possibilities for reducing vent sizes to less than human-passable using multiple honeycombs should be considered. In some cases, the exhaust system machinery itself may add to penetration time. (37) 13.1-108

Roof-mounted equipment--Although expensive, the only known way of providing extended penetration time for human-sized openings exposed by removing roof-mounted machinery is to provide a hardened "penthouse" to house the machinery. Penthouse penetration time will depend on structural components, doors, and openings used. Specific penetration times can be estimated by the same methods described for structures throughout this manual. Otherwise, multiple, small ports in the penthouse structure with multiple grills must be considered. (37) 13.1-108

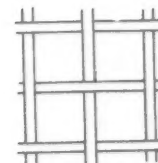
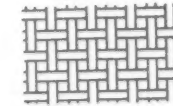
Filter banks--The previous discussion on roof-mounted equipment applies in general to filter banks, except that the banks themselves are unlikely to offer any significant penetration time. An enclosure prepared with one of the vent or duct hardening techniques previously described appears to be the best approach. (37) 13.1-110

Miscellaneous openings. Structure openings such as skylights, roof-hatches, scuttles, elevator shafts, ash dumps, rubbish chutes, fire escapes, and roof access ladders offer access to intruders and should be considered in hardening plans. The first step should be to eliminate openings that are not absolutely necessary. The approach to upgrading those that remain will be dictated by the structural elements involved, that is, by suitable design of walls, roofs, doors, and locking mechanisms. (37) 13.1-110

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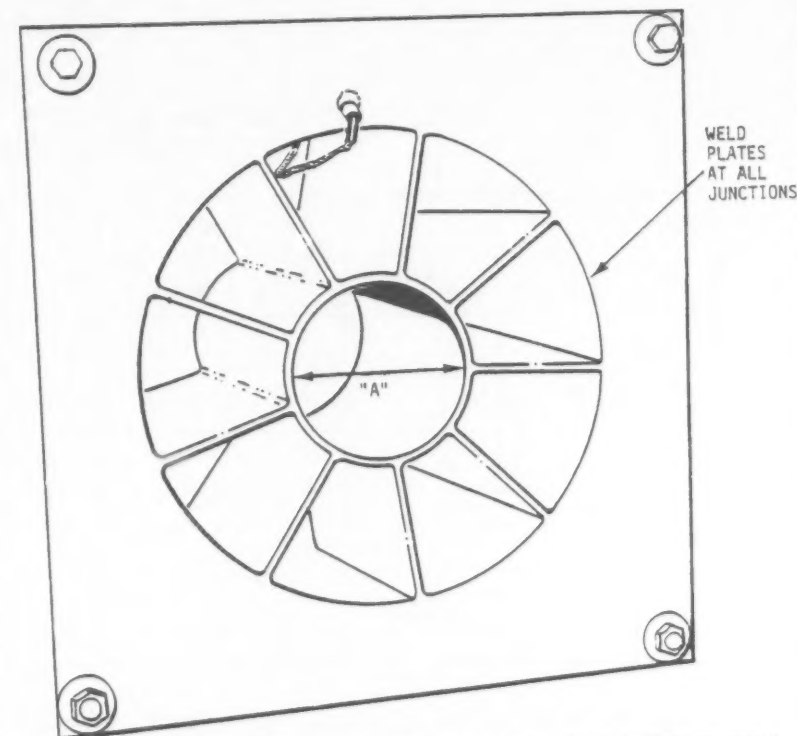
GRIDS AND GRATES

3/4-IN MESH,
0.148-IN WIRE3/4-IN MESH,
0.135-IN WIRE3 MESH,
0.162-IN WIRE4 MESH,
0.120-IN WIRE

WIRE MESHES

WIRE MESHES, GRIDS, AND GRATES. (153) 8-7

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DIAMETER "A" MUST NEVER BE LARGER THAN 10 in (250mm). NO OPENING SHALL BE LARGER THAN 90 SQUARE INCHES (0.6m²) IN AREA. PLATE PLACEMENT AND CONFIGURATION MAY BE VARIED TO MEET NEED OF EACH INSTALLATION. UNIT CAN BE FABRICATED AND WELDED/BOLTED IN PLACE OR BUILT INTO EXISTING OPENING. ROUND OPENING WITH STEEL PLATE BARRIERS. ALSO APPLICABLE TO OTHER OPENING CONFIGURATIONS.

VENT FRAME HARDENING. (37) 13.1-109

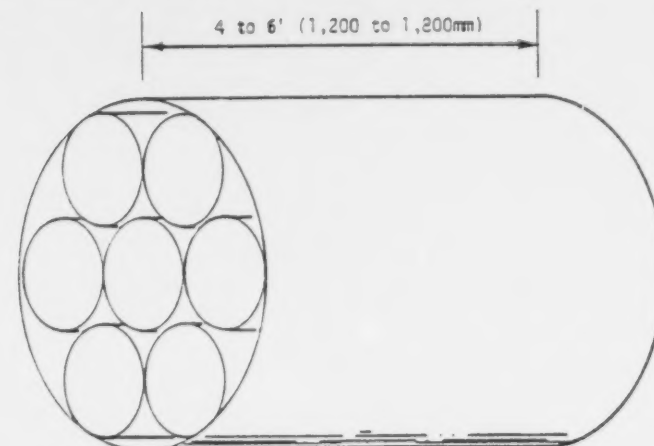
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TIME AND NUMBER OF CUTS REQUIRED TO ALLOW HUMAN ENTRY INTO GRILLS
COMPOSED OF VARIOUS SIZE BARS AND BAR SPACINGS*

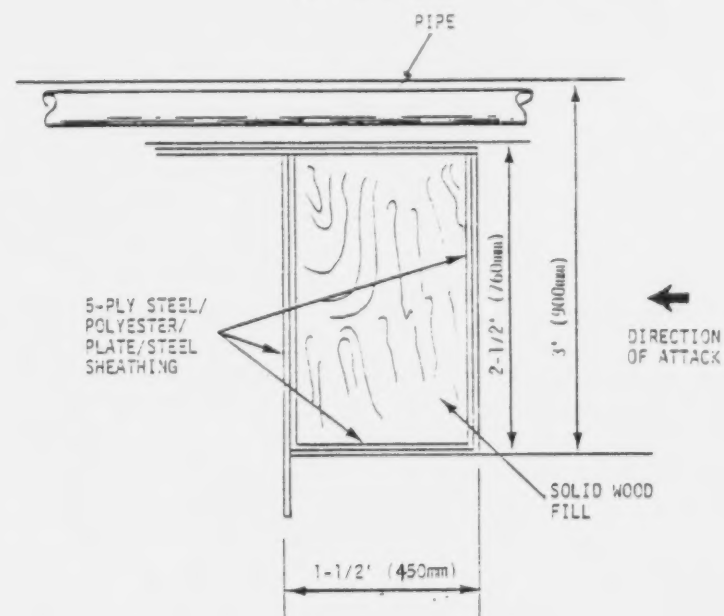
Bar no. spacing, in. (mm)	3		4		5		6		7		8	
	Time	Cuts	Time	Cuts	Time	Cuts	Time	Cuts	Time	Cuts	Time	Cuts
3 (75)	1.2	12	1.7	12	2.5	12	3.5	12	5.1	12	7.9	12
3.5 (90)	0.8	8	1.2	8	1.6	8	2.3	8	3.4	8	5.2	8
4 (100)	0.8	8	1.2	8	1.6	8	2.3	8	3.4	8	5.2	8
4.5 (115)	0.8	8	1.2	8	1.6	8	2.3	8	3.4	8	5.2	8
5-9 (125-225)	0.4	4	0.6	4	0.8	4	1.2	4	1.7	4	2.6	4
>10 (250)	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0

*Estimates are for a single-layer grill composed of steel bars with diameters shown, equally spaced both horizontally and vertically. Times shown are total time measured in minutes required to provide a human-passable entry of at least 96 square inches (0.06 square meters). Cuts shown are the minimum total number of bars that must be cut to provide entry. All bars, grills, security screens, etc. should be located inside windows, behind glazing material. Glazing material should be protected by intrusion detection sensors that provide an alarm before the intruder begins penetrating the bars. (37) 13.1-96

guidance SECURITY/4 Zone 3



SECTION OF LARGE SEWER PIPE RENDERED HUMAN-IMPASSABLE BY 4- TO 6-FOOT (1200 TO 1800 MILLIMETER) LONG SECTIONS OF HONEYCOMB MADE BY WELDING SECTIONS OF PIPE WITH SMALL DIAMETER.
(37) 13.1-104



CONSTRICTED PIPE CHASE, CROSS SECTIONAL ELEVATION VIEW.
(37) 13.1-106

guidance SECURITY/4 Zone 3

6. Hardware

Locking systems

These can be broadly classed as external, surface-mounted or internally mounted. External systems typically involve some type of lock with an external hasp exposed to a potential attack from the outside. Therefore, internal locking systems are preferred, particularly for high-security facilities. Unfortunately, applicable designs for internal locking systems are under development and, thus, penetration data are not yet available. The best available systems recommended in subsequent paragraphs therefore emphasize external systems. The types of approved locks and hasps are listed in the next table. In general, the types of approved locking system in use can be divided into low-, medium-, and high-security categories. For attacks involving optimal combinations of tools, the expected penetration times by forced entry attacks range from less than 7 minutes for high-security systems to practically no time for the low-security systems. Corresponding surreptitious entry times involving lock picking are: high- and medium-security--30 minutes; low-security--40 to 60 seconds. For less than optimal attacks, penetration times as high as 15 to 30 minutes may be possible with high-security systems. In general, it should be noted that a lock and hasp system offers maximal penetration resistance only when it is properly installed on a strong door with appropriate hardware.

In general, state-of-the-art developments in locking systems are changing so rapidly that the security engineer should contact qualified Navy RDT&E personnel. For information on hardening of locking systems, including external and interior locking devices integral to door systems, as well as hasps, the security engineer should contact: NCEL, Naval Construction Battalion Center, Port Hueneme, CA 93043. (37) 13.1-70

READER
FICHE

guidance SECURITY/4 Zone 3

SUMMARY OF LOCKS AND HASPS. (37) 13.1-71

Level of security	Type of unit	Military Federal specifications	Lock/hasp description	Navy stock number	Forced Entry penetration time (minutes)	Surreptitious entry-picking time (minutes)
High	Key padlock	MIL-P-43607 (Latest edition)	Key operated, shrouded shackle, deadbolt padlock	5340-00-799-8248	< 7	30
	Key locking device	MIL-L-29151 (Latest edition)	Key operated, high-security deadbolt lock 5340-00-145-0293	5340-00-144-7310 5340-00-144-7311		
	Mounted combination lock	MIL-L-15596 (Latest edition)	Surface-mounted combination locking device	534-00-144-7359		
	Hasp	MIL-H-29181 (Latest edition) security padlocks	High-security, shrouded hasp for high and medium	NAPEC 0957 NAPEC 0958		
	Hasp	MIL-H-43905 (Latest edition)	Hasps for high security padlocks Style 2 (carbon steel) 5340-00-178-7873 Style 3 (carbon steel) 5340-00-178-7875 Style 4 (carbon steel) 5340-00-178-7880 Style 5 (carbon steel) 5340-00-178-7881 Style 6 (carbon steel) 5340-00-178-0019	Style 1 (carbon steel) 5340-00-178-7872		
Medium	Key padlock	MIL-P-43951 (Latest edition)	Key operated, regular shackle deadbolt padlock	5340-00-492-1993 5340-00-799-8016	< 4	30
Low	Combination padlock	FF-P-110 (Latest edition)	Three-position, dial-type combination padlock 5340-00-292-0896	5340-00-285-6523 5340-00-285-6524	< 1	0.67-1
	Key padlock	MIL-P-17802 (Latest edition)	Key operated, pin tumbler padlocks	Over 40 stock numbers		

guidance **SECURITY/4 Zone 3**

High-security locks and hasps--Those meeting the high-security level requirements are used when the greatest degree of protection is required against forced and surreptitious entry. (37) 13.1-70

High-security padlocks. Only one padlock is authorized for procurement under MIL-P-43607. This padlock is called "shrouded shackle" because of its design. The body is extended high enough to provide a complete protective cover (shroud) around the shackle, which prevents easy access for attacks directly against the shackle. This padlock is equipped with a 1/2-inch (13-millimeter) shackle and is keyed individually. When used with a high-security hasp, this high-security padlock provides a high degree of resistance to surreptitious entry and offers the most resistance to forced entry currently available. It should be noted that a high-security padlock provides the specified degree of security only when it is used with a high-security hasp; investment in an expensive high-security padlock is wasted if the lock is attached to an inexpensive, low-security hasp. (37) 13.1-72

High-security locking devices. The type that meets MIL-L-29151, a precision cast, stainless steel lock, is a unique, self-contained, low-profile locking device that provides a high level of security. Its design allows it to be used for outward, double swinging, sliding, and roll-up doors. This device incorporates a durable interlocking cast construction with an integral hasp and a central bolt assembly. The two interlocking wings are mounted directly to the closure, either welded or bolted, and are free of annoying hasps, chains, or other loose parts. This design ensures that the lock cannot be removed for unauthorized use. The unit is keyed individually and the key retaining function results in a locked open or closed position when the key is removed. The concept allows versatile mounting and is suitable for most security applications. (37) 13.1-72

High security hasps. Those approved for high-security use include the padlock styles 1 through 6 and the high-security shrouded system. Styles 1 through 6 consist of two unhinged, carbon steel parts designed specifically for the land facilities. A carbide wire on the inside face of each part is intended to slow sawing attacks on the hasp. When secured with an approved high-security padlock, the hasp protects the padlock shackle from attack. Although designated "high-security," styles 1 through 6 nevertheless leave the lock itself open to attack. NCEL developed a high-security shrouded hasp system (MIL-H-29181) to minimize this problem. This system is shown in the figure "High Security Hasp." (37) 13.1-72

guidance **SECURITY/4 Zone 3**

Mounted combination locks. One such locking unit meeting MIL-L-15596 is specially designed for use on wood and metal doors at secure spaces, such as those for communications and intelligence. It is a reversible, surface-mounted lock recommended for use on doors at high-security areas. In essence, it is two locks in one, a deadbolt and a combination lock. The deadbolt section features hardened steel pins and an interlocking strike and frame to prevent jimmying or spreading of the door frame. It has an inside release knob for convenient exiting and an automatic deadlocking trigger. This trigger enables it to be locked while the door is open, but activates the bolt when the door is closed. (37) 13.1-78

Medium-security locks--Padlocks meeting medium security requirements must protect against forced and surreptitious attacks. In general, these locks provide a high degree of resistance to surreptitious entry (30 minutes), but only minimal resistance (4 minutes) to forced entry. They are expensive and, therefore, should be used only when prevention of surreptitious entry is essential. Only two medium-security padlocks currently qualify under MIL-P-43951. They differ only in their shackle diameters and in the way each model is keyed. Style 1 is used with reduction gear-casing and associated engineering equipment only. It is equipped with a 3/8-inch (9-millimeter) shackle and is keyed alike in sets of 10. Style 2 meets all other medium-security needs. It is equipped with a 1/2-inch (13-millimeter) shackle and is keyed individually. (37) 13.1-78

Low-security locks and hasps--These satisfy most access control requirements for offices and other noncritical spaces at which hasps and padlocks can be used. Access control protects records, office equipment, supplies, and personal items and limits accountability to personnel staffing and maintaining these spaces. These locking systems should only be used when their intended purpose is to deter unauthorized entry. They provide no resistance to forced entry and only minimal resistance to surreptitious entry. Various types of low-security locks and hasps are available. (37) 13.1-78

Low-security padlocks. Those shown in the corresponding figure are just a few of the hundreds of different models that have been purchased under MIL-P-17802. Locks are key-operated pin tumblers with five or six tumbler pins, and can be purchased, keyed individually, master, grandmaster, and alike. (37) 13.1-78

Low-security hasps. These are available in standard stock. The security value of a low-security hasp must be rated minimal. The hasp is usually the weakest part of a

guidance SECURITY/4 Zone 3

locking system. Almost any lock provides more resistance to forced entry than the low-security hasp. Low-security hasps should be used only when access control, not security, is the basis for installation. (37) 13.1-82

Combination padlocks. The two most common types of these locks are the three-position changeable combination padlock and the bottom-reading, disk-type, changeable combination padlock. The three-position changeable combination is a front-reading dial-type padlock with a capacity of 125,000 possible combinations. It is equipped with a 5/16-inch (8-millimeter) shackle made of hardened steel. The bottom-reading, disk-type, changeable combination padlock has a capacity of approximately 10,000 possible combinations. It has a 5/16-inch (8-millimeter) steel shackle. Both padlocks use special keys to change the existing combinations. Changeable combination padlocks should be used when it is desirable that no keys be removed from the facility. Although both changeable combination padlocks can be used for low security, only the three-position changeable combination padlock is authorized for protecting classified material. (37) 13.1-82

Mounted combination locks. These are physically mounted to the opening of the space secured. These opening members can be safe doors, filing cabinet drawers, or vault or room doors. When properly mounted, the lock itself is protected by the space it secures. When the space is closed and locked, the only accessible part of the lock is the dial and dial ring. When mounted to safe or vault door, added protection is provided by the hardened steel plates used in these doors (see the figure "Mounted combination locks"). Although mounted combination locks afford different degrees of protection, the method of operation and installation are basically the same. They are divided into two types based on how the combination is changed--by key or by hand. The changing of a combination on a mounted lock is critical; if improperly done, lockout may result. Neutralizing a lockout can be time consuming and costly, and may result in irreparable damage. Careful study and a sure knowledge of the procedures used for each type of mounted lock is essential. Combinations should be changed only by an authorized, properly cleared person who has been trained in the correct procedure. (37) 13.1-82

Mortise locks. These are so-named because the lock case is mortised or recessed into the edge of the door. The most common type has a knob on each side of the door. Either knob will operate the latch bolt. This lock can be locked from the inside by a thumb turn whereas a key is required to lock or unlock it from the outside. (37) 13.1-86

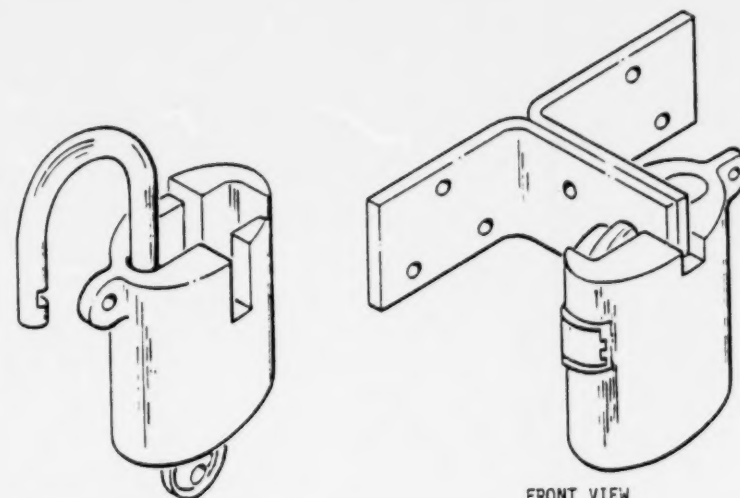
guidance SECURITY/4 Zone 3

Cylindrical locks. The cylindrical or key-in-knob lock has its locking cylinder in the door knob. Some cylindrical locks require a key to lock and unlock them. Others unlock with a key, but must be locked by pushing or rotating a button on the inside knob. (37) 13.1-86

Deadbolt locks. These are sometimes called "tubular deadbolts." They are similar to the cylindrical lock in that they are mounted in a hole cut through the door. The primary difference is in the bolt. When this bolt is extended (locked), it cannot be pushed back (unlocked) by applying end pressure to the bolt. (37) 13.1-86

Hinges and door/frame interface hardening options-- Additional concepts for hardening personnel doors involve positive interlocking hardware for coupling the hinge sides of the doors to the door frames. For installing hardened doors, the facilities engineer should consider the strength of the door jamb as part of a secure door system. Hardening the upright surfaces into which the door is fitted (for example, installing steel uprights) will prevent jamb attacks. (37) 13.1-86

guidance SECURITY/4 Zone 3

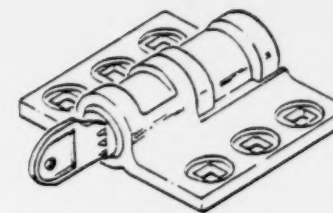
BACK VIEW WITH
SHACKLE OPENFRONT VIEW
WITH HASP

BOTTOM VIEW

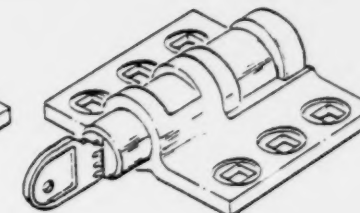
BACK VIEW WITH
SHACKLE CLOSED

HIGH-SECURITY PADLOCK. (37) 13.1-73

guidance SECURITY/4 Zone 3



LOCKED



UNLOCKED



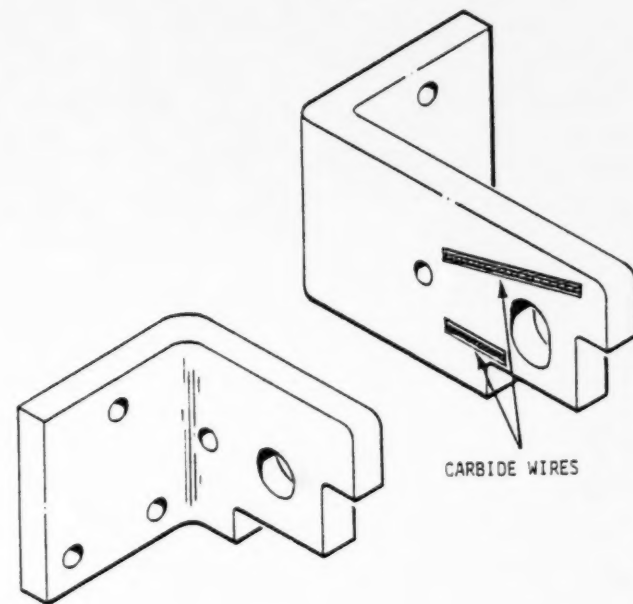
OPEN



KEY

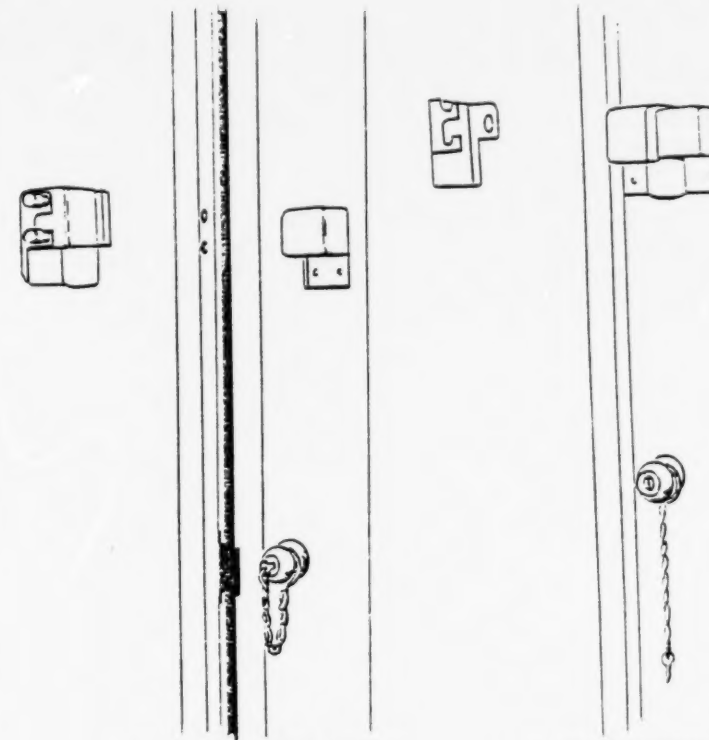
HIGH-SECURITY LOCKING DEVICE. (37) 13.1-74

guidance SECURITY/4 Zone 3



HIGH-SECURITY HASP. (37) 13.1-75

guidance SECURITY/4 Zone 3



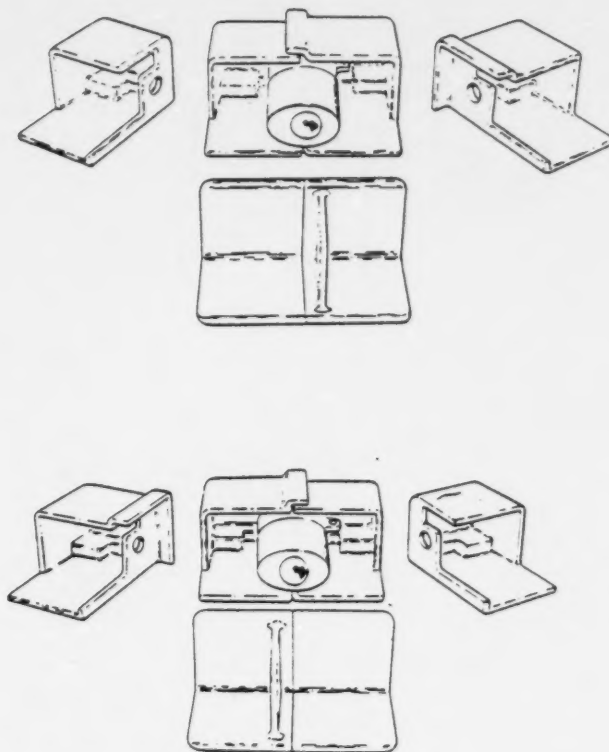
A) OPEN POSITION; HASP/LOCK
IN SECURE STORAGE MODE

B) LOCKED POSITION

NOTE: SYSTEM MODIFIED BY ADDITION OF SIDE PINS ALLOWS THE
LEFT PORTION OF THE HASP SYSTEM TO BE REMOVED AND
STORED SO THAT IT DOES NOT OBSTRUCT THE DOOR OPENING.

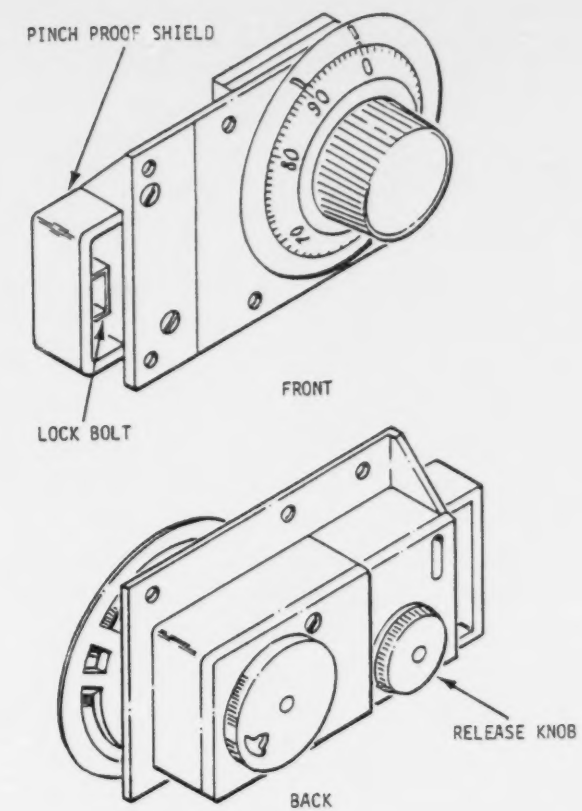
NAPEC 0957/0959 HIGH-SECURITY/HASP/LOCK SYSTEM. (37) 13.1-76

guidance SECURITY/4 Zone 3



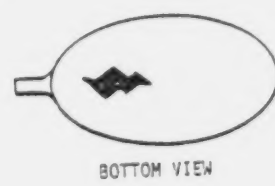
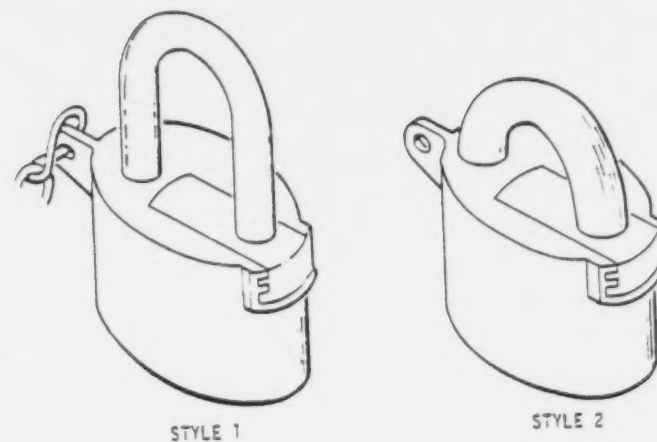
NAPEC 0957 AND 0958 HIGH-SECURITY HASP FOR HORIZONTALLY OR VERTICALLY SLIDING DOORS. (37) 13.1-77

guidance SECURITY/4 Zone 3



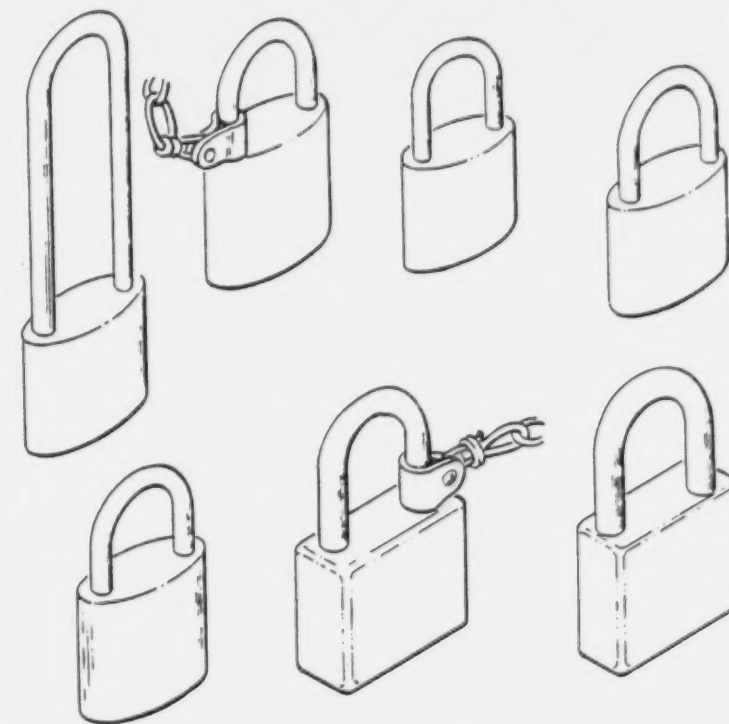
MOUNTED COMBINATION LOCK. (37) 13.1-78

guidance SECURITY/4 Zone 3



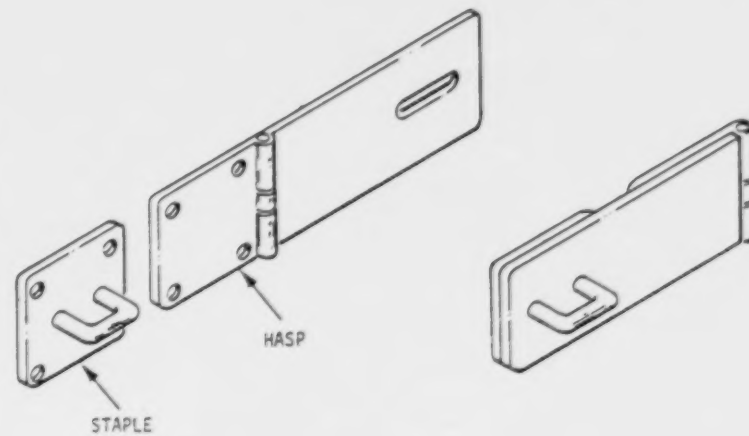
MEDIUM-SECURITY PADLOCK. (37) 13.1-80

guidance SECURITY/4 Zone 3



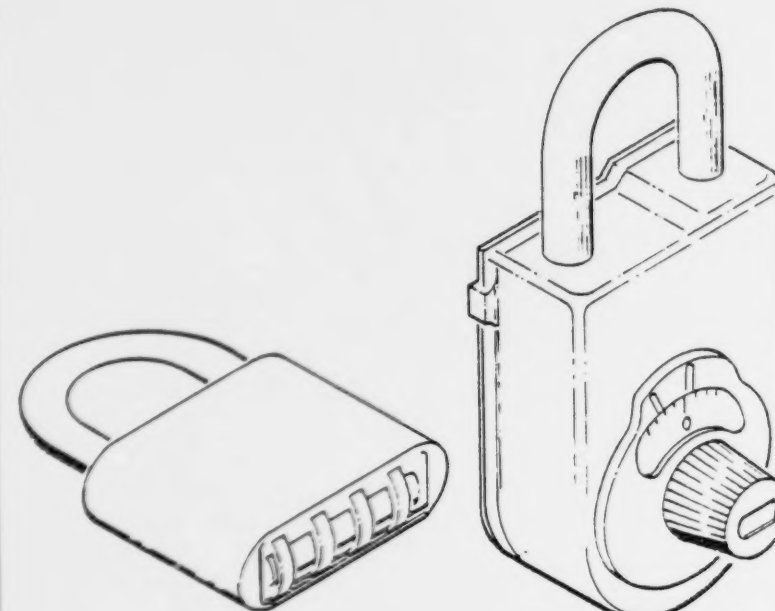
LOW-SECURITY PADLOCKS. (37) 13.1-81

guidance SECURITY/4 Zone 3



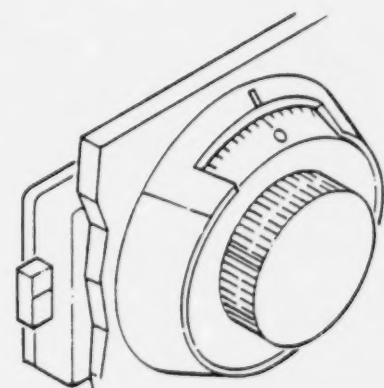
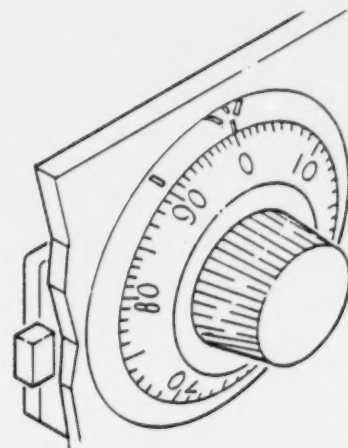
LOW-SECURITY HASP. (37) 13.1-83

guidance SECURITY/4 Zone 3

BOTTOM READING,
DISK TYPETHREE POSITION CHANGEABLE
COMBINATION PADLOCK

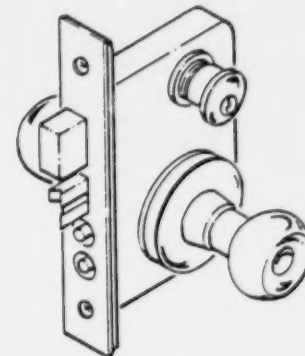
COMBINATION PADLOCKS. (37) 13.1-84

guidance SECURITY/4 Zone 3

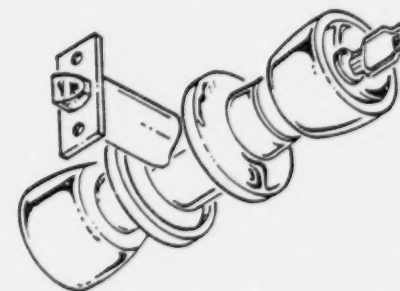


MOUNTED COMBINATION LOCKS. (37) 13.1-85

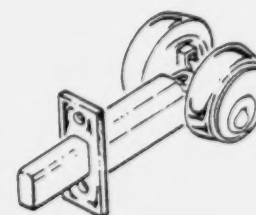
guidance SECURITY/4 Zone 3



MORTISE LOCK.



CYLINDRICAL LOCK.



DEADBOLT LOCK. (37) 13.1-87

guidance SECURITY/5 Zone 4**5. a. Zone 4 security measures**

Security measures are installed in zone 4. (9) 5.1.3.6

1. Inner barrier

For protection, all essential equipment and power sources in buildings at unmanned DCS sites shall be consolidated and then housed in vaults. Only equipment necessary to the communications function of the site shall be afforded this protection. Existing trailers, vans, or portable vaults can be substituted for the equipment vault as long as these structures are contained inside a building. (9) 5.1.3.6.1

See 5b of this section.

2. Area within the inner barriers

See 5b of this section

3. Towers and tower legs

All tower legs at manned and unmanned DCS sites shall be protected. (9) 5.1.3.6.2

4. Guy wires and guy wire anchors

All guy wire anchors shall be encased in sleeves. (9) 5.1.3.6.2

5. Electronic equipment

6. Power and fuel sources

guidance SECURITY/5 Zone 4**b. Intrusion delay to protect critical assets**

Security measures are installed in Zone 4 to protect "critical" assets through intrusion delay.

Vaults

Material deposited in a vault may not be secure from theft since vaults can be penetrated in several ways if the adversary has access, time, and proper equipment. Vaults considered in this section are large, walk-in types with either single-leaf or double-leaf doors and concrete, steel, or concrete-steel walls, floors, and ceilings. Usually they are inside a larger structure and not free standing.

A vault consists of four basic structural elements--floor, walls, roof, and door(s)--which should meet specific criteria for material containment. In addition, some vaults require ventilation ducts that must be considered potential entry paths for adversaries.

A design that has been used for some vaults (next figure) is one for which walls, roof, and floor are made of (1) 0.5-inch-thick steel with fireproofing, (2) 8-inch-thick reinforced concrete, or (3) 12-inch-thick nonreinforced concrete, any of which can be penetrated rather quickly with the proper tools.

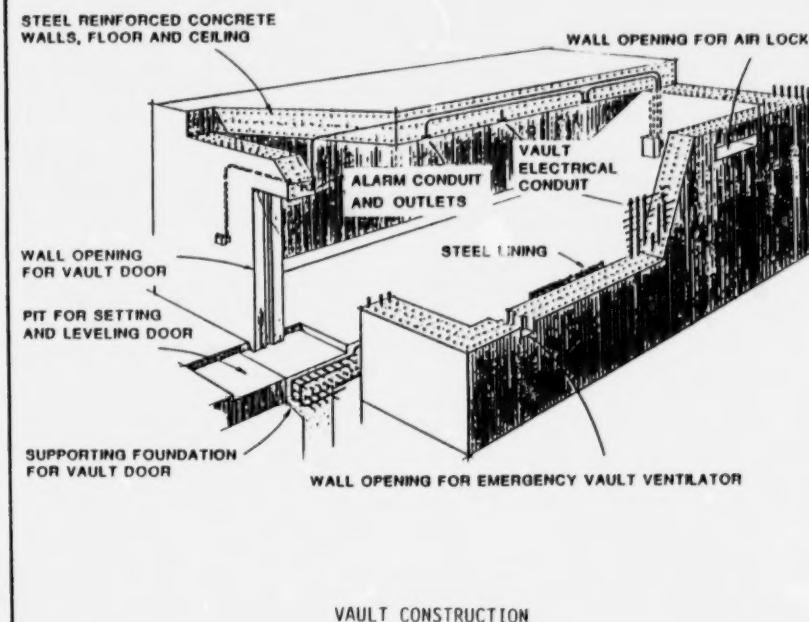
The Bank Protection Act of 1968 (revised 1973) and the Insurance Services Office have different standards for vault construction, specifically, for the thickness of walls, roof, floor, and doors. These standards comprise seven classes with several different construction options for walls, roofs, and floors. In general, as the sensitivity of the vault's contents increases, the resistance to penetration of walls, doors, and other elements should also increase.

The part entitled "Intrusion Delay and Penetration Resistance for Walls" (Security 4b) contains extensive information about steel walls, reinforced concrete walls of various thicknesses and steel placements (deformed rebar and expanded steel bank vault mesh, 3.63 pounds per square foot), fibrous concrete walls, composite walls, stand-off walls, and others, many of which have been tested with penetration times established.

Location--The location of a vault inside a building could be a factor in determining its penetration resistance, for example, placement on an exterior wall versus placement completely inside the building. An exterior wall location may give an adversary a stealthy penetration path; or, it could permit the use of explosives on the wall or roof with the same

guidance **SECURITY/5 Zone 4**

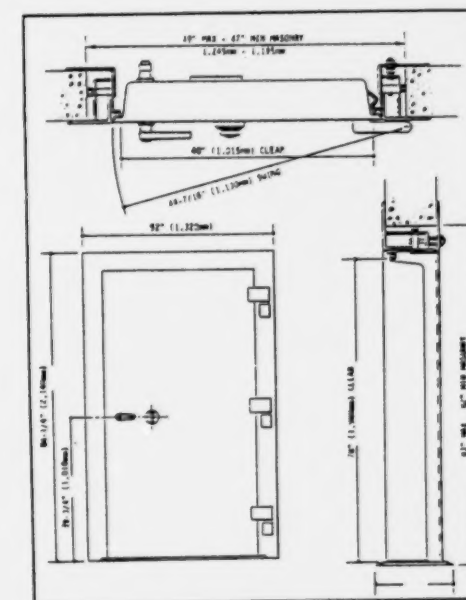
ease with which an exterior building wall could be attacked. When the vault is placed inside the building, the adversary may be reluctant to use explosives or may be limited in the amount he or she could detonate without causing a structural failure from overpressure, shrapnel, or both.



Openings--The openings for vault door(s), ventilation ducts, and other parts may be a weak point in an otherwise hardened structure. However, since openings are necessary for access and utilities, they should be considered in the vault's overall penetration resistance.

guidance **SECURITY/5 Zone 4**

Vault doors--Vaults are defined as strong rooms for storing classified information. The U.S. Navy has criteria and standards that form a basis for uniform construction of security vaults. These are specified in the Security Manager Handbook prepared by the Security Information Division, Office of Naval Intelligence (pages 11-13 through 11-16). By definition, class A and B vaults require a class 5 vault door, whereas a class C vault requires a class 6 vault door. Class 5 and 6 vault doors are available on the Federal Supply Schedule. The door requirements are specified in Federal Specification AA-D-600, copies of which can be obtained from any regional office of the General Services Administration (GSA). In general, a class 6 vault door is primarily a fire door and is not intended to provide forced entry protection; it is only recommended for "confidential" level classified material. The following figure shows a typical GSA class 5 vault door. In addition to vaults, class 5 doors are authorized for AS&E storage facilities. As with personnel doors, class 5 door have penetration times less than 1 minute against optimal attack tools. (37) 13.1-65



VAULT DOORS. (37) 13.1-66

guidance SECURITY/5 Zone 4

Class 5 vault doors, which conform to Federal Specification "Door, Vault, Security AA-D-600B," dated 26 March, 1969, revised June 13, 1973, theoretically afford the following security protection:

- 30 man-minutes against surreptitious entry
- 10 man-minutes against forced entry
- 20 man-hours against lock manipulation
- 20 man-hours against radiological techniques

Testing performed in accordance with this specification limits a two-person attack team to the use of hand tools and devices that cannot be (1) more than 20 inches long when disassembled or folded, (2) carried in a case exceeding 1.5 cubic feet in volume and 9 inches in thickness, and (3) in excess of 25 pounds, excluding the case. Further, no explosives or thermal devices are permitted, which, in light of current threats, leaves this door potentially vulnerable to rapid penetration by either method.

Tests on the class 5 vault door indicate that penetration can be done with power tools, thermal tools, or explosives in 1 to 5 minutes. Other types of vault doors, such as the lightweight mercantile and the heavy bank types, may also be suitable for selected security purposes and may offer significant penetration resistance for respective threats. However, no penetration times have been established for these doors.

Locking mechanisms--In general, the locking mechanisms used on doors for security are combination locks coupled to engage bolts; they are tested to withstand 20 man-hours of lock manipulation. However, the typical class 5 locking mechanism is vulnerable to penetration by hand tools, thermal tools, hand-held power tools, and explosives. Tests have shown that penetration is possible in 2 to 5 minutes. Other locking mechanisms are available with additional features such as automatic deadbolts that are activated by drilling or by thermal or explosive penetration attempts, time locks, wedge locking bars, and locking thresholds. These locking mechanisms will require evaluation before improvements in delay resistance can be established.

guidance SECURITY/5 Zone 4

Vaults: conventional construction

Vaults and secure storage rooms criteria (138) 3-59--These criteria include construction of vaults and secure storage rooms for storing classified matter and records. When vault walls are part of exterior walls, the vault wall should be set behind the exterior face of the outside wall to allow 4 inches of the normal wall facing material to cover the vault. Since doors purchased for class A and B vaults will not normally be fire rated, provide an automatic wet-pipe sprinkler system inside that has a water-flow device to sound a local alarm and transmit a signal to a central alarm.

Class A vault for storing classified materials--This is a repository that can be used to store classified materials under conditions stipulated in AFR 205-1. Supplemental security features normally are not required.

For constructing the class A vault, floors and walls shall be 8-inch-thick reinforced concrete. Walls will extend to the underside of the roof slab above. The roof shall be monolithic reinforced concrete slab of thickness to be determined by structural requirements, but not less than wall and floor thickness. When the underside of roof slab or roof construction exceeds 12 feet high or when roof construction is not in accordance with that just described, a normal reinforced concrete slab ceiling will be placed over the vault area at a height not to exceed 9 feet.

Except as specified herein, the door and frame shall conform with the requirements of Federal Specification AA-D-600b for a class 5 door. Door openings shall be standard 40 by 78 inches without a day gate. The door and frame do not have a fire rating. The door shall have emergency escape and relocking devices.

The lock shall conform with Underwriters Standard No. 768, Group 1-R, shall be manipulation-resistant, and shall meet AA-D-600b for radiological resistance. The Underwriters label will be considered evidence of compliance with these requirements. The door shall have a GSA-approved label for a class 5 door.

Class B vault for storing classified material--The minimum desirable protective design for essential communications facilities (including back-up power) shall be a class B vault. Although this requirement primarily applies to new facilities, existing structures should be modified to approach Class B vault construction standards when economically feasible. No windows are permitted. (11)

guidance SECURITY/5 Zone 4

The Class B vault is a repository that can be used to store classified materials under the conditions stipulated in AFR 205-1. The classification of Class B vaults can be upgraded by added supplemental security features or by an inherently secure environment.

For constructing the Class B vault, floors shall be monolithic concrete of the same thickness as adjacent concrete floor construction; however, vault floor slab will be not less than 4 inches thick.

Walls shall be no less than 8 inches thick and should be made of brick, concrete block, or other masonry units. Hollow masonry units shall be vertical cell type (load bearing) and shall have cells filled with concrete and steel reinforcement bars. In seismic zones 2, 3, and 4, use steel reinforced monolithic concrete walls no less than 4 inches thick.

The roof shall be monolithic reinforced concrete slab of a thickness to be determined by structural requirements. When the underside of roof slab or roof construction exceeds 12 feet high or when roof construction is not in accordance with that just described, a normal reinforced concrete slab ceiling will be placed over the vault at a height not to exceed 9 feet.

Except as specified herein, the door and frame shall conform with the requirements of a class 6 door in Federal Specification AA-D-600b. Door openings shall be standard 40 by 78 inches without a day gate. The door shall have emergency escape and relocking devices.

The lock shall conform with Underwriters Standard No. 768, Group 1-R, shall be manipulation-resistant, and shall meet AA-D-600b for radiological resistance. The Underwriters label will be considered evidence of compliance with these requirements. The door shall have GSA approved label for a class 6 door.

Secure storage rooms--A secure storage room is any designated room that increases security protection through supplemental measures such as intrusion detection alarm systems, guards, guard patrols, or personnel on duty. Rooms selected or constructed for this purpose shall consist of an interior space enclosed by or separated from other similar spaces by four walls, a ceiling, and a floor, all constructed of solid building materials. Removable panels and the like shall not be used. Windows and other openings shall be enhanced by covering with number 9 gage, 2-square-inch steel mesh or 1/2-inch steel bars installed no more than 6 inches apart. The room must be constructed so as to provide a physical barrier that cannot be breached without leaving

guidance SECURITY/5 Zone 4

evidence of actual or attempted entry into the secure room. If an alarm system is used, it must, as a minimum, provide immediate notice to a security force whenever surreptitious or forced entry is attempted. Vault doors or other substantial doors can be used as compatible with the environmental, supplemental support and operating requirements.

Vault doors are to be selected from the doors specified for Class A and B vaults above.

Substantial doors for secure storage rooms have two-ply wood cores covered with 26-gage galvanized steel, with each wood ply no less than 25/32 inch thick. The two-ply doors shall be constructed with one wood layer vertical and the other horizontal. An alternative is to use a 1-3/4 inch thick door with a solid wood core covered with 26-gage galvanized steel.

Frames for substantial doors of secure storage rooms shall be of 16-gage hollow metal or of structural steel channels as compatible with the strength of the wall construction.

Provide tamper-proof, heavy-duty fixed-pin door hinges or butts. Install a manipulation-proof, three-position, dial-type combination lock with an interior safety release turn knob which conforms to Underwriter's Standard UL 768, Group 1.

When necessary, the substantial doors can be stripped around the edges and at the sill to prevent transmission of sound from the secure storage room. Provide buzzers where required.

Crypto work room (not a vault) ([138] 3-61). This is a room providing the workspace required for encoding and decoding. Normally, a safe or vault is provided in this room to house and secure crypto matter when not in use.

For construction, exterior walls shall be the same as for the basic structure. Enclosing partitions will be of normal construction, with a minimum 1-hour fire resistance rating. Combustible material will not be used as wall and ceiling finishes.

Soundproofing will be to a degree that will not allow the type of operations to be recognized by interpreting mechanical sounds. This soundproofing will be evaluated apart from the soundproofing requirement for personnel and equipment in the crypto room.

Omission of windows in the crypto room is desirable, but not mandatory. When installed, they must be barred and screened in so as to prevent viewing of the room from any outside point.

guidance SECURITY/5 Zone 4

When a room has a vestibule, the inner door can be standard grade commercial wood or metal. The outer door to the room can be either commercial solid wood or metal with the same fire resistance rating as the enclosing partitions of the room. The door frame will be metal of minimum 16 gage.

Heavy-duty hardware with an integral locking device operable from the inside is good enough for normal operation. For special operating conditions, an approved lock, such as a three-tumbler, 100-number face dial with a changeable combination can be used by the local commander. When a combination lock is used, the crypto work room will have a phone and an alarm device. The alarm will transmit to a central manned location by any person who might be accidentally locked in the room. Instead of the above combination lock and alarm, install a manipulation-proof, three-position, dial-type combination lock with an interior safety release turn knob that conforms to Underwriters Standard UL 768, Group 1.

Improved design concepts

Existing vaults usually consist of a hinged steel vault door mounted in a reinforced concrete structure. Penetration times with hand, power, and thermal tools are usually less for the vault's door than for its walls, floor, or ceiling. Because of the greater penetration delay time it affords, a reinforced concrete door the same thickness as the surrounding structure could replace a steel vault door to balance the vault's overall penetration resistance.

Evaluation of door, window, and utility opening design options--In general, data indicate that conventionally constructed doors, windows, and utility openings offer very little attack resistance (typically less than 2 minutes). Attack-hardened single barrier door options for which data are available offer penetration times up to nearly 30 minutes. These door surfaces are constructed of a multilayered wood/steel combination. The facilities engineer should note, however, that these penetration times apply only to door surfaces; they do not apply to locking devices that are integral to the secure door system. No state-of-the-art locking devices provide penetration resistance in excess of 7 minutes. A user seeking to design a 30-minute door, for example, might consider using multiple locking devices. Although definitive test data are not available, the use of thick, massive, blast-hardened doors made of reinforced concrete or thick, metallic bank-vault-like doors may lead to higher single barrier penetration times, estimated to be more than 1 hour. Attack-hardened single barrier window options are available that offer up to 8 minutes of penetration time. These options use steel bar grills, which, if used in multiple layers, give higher penetration times. (37) 13.1-60

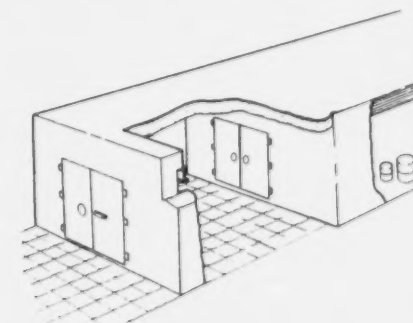
guidance SECURITY/5 Zone 4

As noted earlier, this manual stresses ways to increase penetration time against well equipped, determined intruders. Many enhancements that may not significantly increase the penetration time against a determined intruder can force the use of heavier, more sophisticated tools, which may deter an intruder with less motivation. (37) 13.1-59

Enhancements and advanced concepts

Some existing vaults and vault doors may not provide the penetration delay time considered necessary for certain security systems. The balanced design concept should be followed, that is, avoid the overdesign of one component without offering an adversary another weak part for penetration. It may not be effective to improve the vault structure and not the vault door(s). Conversely, to replace a 3-minute door with a bank-vault door at great expense may improve the door itself, but would not increase the resistance of the overall structure.

One improvement that could provide more thermal penetration resistance to some types of doors is the installation of redwood liners, an addition that has increased cutting time by a factor of four. A vestibule with a second vault door, in which only one door at a time would be open, could be used. The vestibule concept could be coupled with one of the dispensable deterrents for increased penetration resistance.



CUTAWAY VIEW OF VAULT WITH VESTIBULE CONSTRUCTION.

guidance SECURITY/5 Zone 4

Walls (structure)--The vault structure's resistance can be improved by several methods, such as installing a steel liner to form a sandwich wall. This type of wall has been tested by explosives, with the amount of explosives required for penetration increasing by a factor of five. When the vault has exterior wall and roof surfaces, some type of overburden could be used, with the amount limited by the structural design. In addition, the overburden could be enhanced by soil cement, crushed automobile bodies, or other such barriers to increase the penetration time.

Wall concepts that increase resistance to cutting and thermal tools include (1) composite and ceramic materials; (2) different aggregate materials used for concrete, such as lead shot; and (3) ceramic balls. Concepts are also being evaluated for energy absorption to possibly increase flexibility and thus reduce damage from explosives. Stand-off or cavity walls are being studied to determine their ability to absorb blast energy and to improve penetration resistance to thermal attacks. All these concepts could be applied to vaults.

Underground vaults--With these vaults, several feet of reinforced concrete would surround the storage compartment, which would be encased in a floor. Access would be controlled by a coded locking mechanism with an electrical system to lock or close the vault when the facility is under attack. The aboveground vault has many of the same features as the underground vault except that a deep overburden has been used to resist penetration from above.

guidance SECURITY/6 Signal Shielding (TEMPEST)**6.a. Delineation of interior levels of security**

Some fundamental security procedures are required for areas containing equipment that process national security information. The adoption of requisite physical security standards and procedures in accordance with current directives is the user's responsibility. It is recommended that local security officials and others responsible for building construction or modification be contacted in the planning stages of all projects. Since the mission could not be carried out with an absolute security, measures adopted to protect these requirements must be effective, practical, and compatible with local policies and contingencies. To provide for such conditions, in-depth security measures should be established. (133) N-1

To address the different levels of security sensitivity and yet provide the type of protection required, three types of security areas have been designated: controlled, limited, and exclusion. The following definitions are those commonly used in physical security guidelines. Also, physical security nomenclatures apply to physically delineated spaces whereas the equivalent engineering-installation terms are often delineated only on plans. The terms therefore are not necessarily interchangeable. (133) N-1

A controlled space is the three-dimensional space surrounding equipment for processing classified information, within which unauthorized personnel (1) are denied unrestricted access and (2) are either escorted by authorized personnel or are under continual physical or electronic surveillance.

A limited area (limited exclusion area) is an area containing classified information or equipment in which uncontrolled movement would permit access to such material, but within which access may be controlled by escort and other internal restrictions.

An exclusion area is an area containing classified information or equipment of such a nature that essentially constitutes access to the classified material.

Specific guidance

The following guidelines, though not inclusive, pertain to areas inside a facility in which classified information is processed. (133) N-1

Accountability of wire and cables--Complete accountability should be required for all wires and cables in, or passing through, a secure area. All extraneous wiring should be removed. Unused wiring in cables should be grounded in the controlled area. (133) N-1

guidance **SECURITY/6 Signal Shielding (TEMPEST)**

Construction features--Exterior construction should be designed to prevent surreptitious entry. All passages (doors, windows, and vents) into the area should be equipped with hardware that provides security comparable to the exterior walls, floors, and ceilings. Construction methods and materials, as well as the protective measures required, depend on the sensitivity of the information processed in the area. (133) N-1

Adjacent secure areas--Such areas should be viewed as separate entities unless they are of the same classification level and subject to the same personnel access standards. (133) N-1

Guards--Guard personnel for a protected system should have security clearances commensurate with the class of information protected in their duties. Guards may be assigned to stationary or roving patrol posts. They should be formally charged with insuring the area's security. Guards may, in general terms, be told what they are guarding, as the equipment and information in these areas must be protected by other, more direct physical means than those established through normal building guard systems. (133) N-1

Security during construction--Construction and modification of buildings anticipated to house and protect national security information processing facilities are sensitive matters. This sensitivity is increased because uncleared persons are usually employed in the construction or modification processes. The construction period could provide an opportunity for covert devices to be installed or for building materials to be improperly installed, either of which would weaken the installation's security. Properly cleared, qualified engineers or technicians should supervise and inspect the work. Security is vulnerable during the entire construction process; however, particular care should be taken during the finishing phase to prevent covert listening devices from being hidden in walls, behind partitions, or above false ceilings. (133) N-1

NCS-4, "National Policy on Control of Compromising Emanations," exists to prevent the loss of national security information through compromising emanations. To achieve this objective, the effective edition of NACSIM 5100 was developed to provide compromising emanations requirements for new equipment/system development. In some cases, adequate TEMPEST protection may be achieved without full compliance with NACSIM 5100. NACSI 5004 provides procedures for determining countermeasures needed for classified information processors used within the U.S.; procedures for processors used outside the U.S. are contained in NACSI 5005. (198) 1

guidance **SECURITY/6 Signal Shielding (TEMPEST)**

- a. The procedures defined within NACSI 5004 shall be used by all departments and agencies to determine the countermeasures to be applied to equipments/facilities which process national security information within the U.S. Appropriate verification procedures will be used to demonstrate TEMPEST countermeasures acceptability. These procedures will be dictated by the countermeasures employed and will be arranged by order of importance so that it focuses limited TEMPEST resources on those areas deemed most vulnerable to hostile exploitation. No countermeasures are required for systems which do not process classified information.

Where the use of NACSIM 5100 approved devices is indicated, every effort shall be made to use equipments listed on the SCOCE Preferred Products List (PPL).

- b. The requirements shall be used by all departments and agencies to determine the countermeasures to be applied to equipments/facilities which process national security information outside the U.S. Appropriate verification procedures will be used to demonstrate TEMPEST countermeasures acceptability. These procedures will be dictated by the countermeasures employed and will be arranged by order of importance so that they focus limited TEMPEST resources on those areas deemed most vulnerable to hostile exploitation.

Where the use of NACSIM 5100 approved devices is indicated, every effort shall be made to use equipments listed on the SCOCE Preferred Products List (PPL). (199) 2

REQUIREMENTS.

- (1) For each equipment/system/facility processing national security information, both a hazard and a risk factor shall be determined using the procedures of the Annex.
- (2) The TEMPEST countermeasures to be applied shall be determined by using the hazard and risk factors.
- (3) The National Security Agency (NSA) shall, on a semiannual basis, publish a listing of equipments and corresponding TEMPEST information. This document, entitled "TEMPEST Data for Information Processing Equipment," will contain data concerning NACSIM 5100 compliance, PPL status, Equipment Zone assignments, and required controlled space determinations.
- (4) A higher level countermeasure can be used, but it should be recognized that the implementation cost could be higher. In the absence of specific details of cost or operational impact, the indicated countermeasure should be implemented. Use of a higher level countermeasure should be coordinated with the department or agency TEMPEST authority. (199) 2

guidance SECURITY/6 Signal Shielding (TEMPEST)**b. Shielding, filtering and isolation (133) 4-3**

See SB4--"Grounding, Bonding, and Shielding" for detailed guidance.

Shielding

Shielding may be used at many levels, from the individual stage to the entire data processing or communication terminal installation. Shielding separates two regions so that in passing from one to the other an electric or magnetic field (or both) is attenuated by reflection and absorption losses. Shielding can be done with conductor and cable shields, conduit, gaskets, magnetic foils, screens, and shielded enclosures.

Filtering

A filter transmits signals of certain frequencies while attenuating all others. The filters used to contain electromagnetic emanations usually are interference reduction types. They are used on signal, control, and power lines. To perform effectively, they must be selected with care (in some cases special designs are required) and located and installed in accordance with established guidelines.

Isolation

Isolators are devices that provide certain amounts of isolation by attenuating insertion loss between a source and a load. Their function is similar to filters, but their characteristics are usually superior. Circuit isolation is achieved by using transformers, feedback amplifiers, or optical couplers. Other devices useful in power line isolation are active power line filters.

Facility design

The national policy objective is to insure that national security information is not lost through unintentional emanations. To achieve this, equipment should be designed to meet TEMPEST requirements and should be tested to verify compliance with TEMPEST specifications. However, poor installation practices can create system or facility problems, even though all system components are TEMPEST acceptable. Additionally, many installations may be built using non-TEMPEST-approved equipment, and in these instances, proper facility design is imperative.

* See SB4 - Grounding, Bonding, and Shielding

guidance

SB8
Survivability Protection

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SURVIVABILITY PROTECTION

function

Each DCS facility must be able to withstand and function within an environment made hostile by weather, conventional or unconventional warfare, or, in some cases, nuclear detonation. (1) 8 (See SB9-- "Climate Conditions" for weather-related planning and design information.)

The main purpose of "survivability" is to maintain the functioning of each DCA facility. This will ensure the provision of "long-haul" and "point-to-point" communications capabilities to Department of Defense users.

policy / s o p

1. Communications survivability can be increased by (1) alternate routing of communications, (2) rapid restoral of lost capability, and (3) passive defense of communications facilities--that is, a barrier between communications facilities and the enemy. All three are needed to do the job.

2. Consideration should be given to integrating OCONUS DCS facilities with similar host nation communications facilities. In some cases, it may be feasible to install certain antennas among others that terrorist groups would not want to damage. This approach is highly dependent on the political situation (which may change from day to day), and implementation should receive careful analysis before commitment.

3. "Status of force" agreements between host nations and the United States should be honored for facilities not under U.S. sovereign control. (9) 4.18

4. Chemical, biological, and radiological plan.

5. All DCS facilities should have five zones of defense. For sites without enough barriers, the five zones shall be delineated by barriers and by administrative boundaries located approximately where the mission barriers would have been placed. (9) 4-3-3-4-11

Each defense zone should do one or all of the following:

- Provide intrusion deterrence
- Increase intrusion delay
- Facilitate alarm assessment
- Enhance effectiveness of security forces. (9) 4-3-3-4-4

issues and assumptions

6. The overall approach to providing security in DCS sites has five elements:

- Intrusion deterrence
- Intrusion detection
- Alarm assessment
- Component and physical plant hardening
- Security or response personnel. (9) 4-3-3-1

7. The following procedure should be used to develop a site survivability plan:

a. Threat assessment

A profile should be made of each site, including the persons, groups, or organizations, and the type and number of equipment each uses. Scenarios are identified ranging from peacetime to war.

b. Site susceptibilities

These determine the specific operations that maintain the mission and thus help identify failure modes.

c. Site criticality and endurance requirements

Mission versus security involvement is evaluated.

d. Determine appropriate security measures

e. Allocation of resources

Financial, material, and personnel resources, and the services or responses by each unit, are decided.

f. Major threats envisioned at specific locations

Such threats should be determined by security police and intelligence officials.

g. Discussion of survivability criteria

The criteria planned for each location should be discussed and approved by competent security police and intelligence personnel.

h. Determination of vulnerability factors

- Proximity to the battle zone
- Functional importance
- Exposure and access
- Media characteristics. (10) 3-200

policy/ s o p

8. Hardening facilities to withstand the direct impact of conventional weapons may be impractical and too expensive. The goal of such hardening is to complicate the attack effort and to force the time and resources to be expended. (10) 3-301

9. From the DCA document Defense Communications Under Stress, "COMSTRESS" (59.60):

Survivability planning and design analysis: Survivability of the communication system is dependent in part on the planning and design of facilities and equipment deployed at each DCA site. Currently, survivability planning is not standardized throughout the DCS network. Rather, physical hardening requirements are viewed as site specific, with each site dependent upon its own survivability profile.

Physical hardening should improve the survivability of a particular site against both covert and overt attacks. The various survivability options that can be tailored to a specific site increase the probability that the system will remain on the air during the critical early stages of conflict. In essence, physical security measures are designed to buy time for the system.

To achieve the above goals, DCA undertook an analysis effort to predict the effects of conventional war on the Defense Communications System in Central Europe. It was the first in a series of planned analyses relating to the worldwide DCS under stress. The existing network and existing Warsaw Pact offensive capabilities were used as study baselines. The scenario was consistent with DCS planning data and the advice of the intelligence community, especially with DIA.

Combinations of endurance options are necessary to improve endurance over the spectrum of threats. First, physical security improvements are required to provide initial resistance to sabotage attacks. Second, interconnects provide some resistance to effects of sabotage by increasing alternate routing capability. Third, reconstitution is required post-attack to restore loss of critical communications. Fourth, prepositioning is required to improve responsiveness of the restoral/reconstitution effort.

A detailed investigation of U.S. Military, NATO, National Military, and commercial systems in use or planned for Central Europe was conducted. This information provided knowledge on system connectivity, site criticality, and individual site physical vulnerabilities. Next, a detailed investigation was conducted of physical security measures and prepositioning as related to the improvement of system endurance potential.

Each DCS site in central Europe was analyzed according to its existing vulnerabilities and survivability conditions. A damage prediction was developed to determine the impact of covert and overt attack upon the site. From this analysis, guidelines were developed for the physical improvements needed to lower the predicted damage from hostile attack. The physical security options explored do not make a site invincible against a determined enemy.

policy/ s o p

Upgrading the physical hardening for each site requires a survivability profile that analyzes the sites' vulnerability to attack. From this profile, specific hardening requirements can be implemented in terms of increasing overall survivability.

The objective of site hardening is to implement physical security measures and safeguards that make it more difficult to gain access to and penetrate the site and damage and destroy critical components.

The spectrum of possible hardening measures pertains to a number of elements including the access road, perimeter and interior fencing, equipment building, antennas and microwave tower, waveguide transmission line, commercial power lines, fuel tanks, and outside lighting.

The survivability profile is dependent upon several factors that relate directly to the sites' specific location and layout. The location becomes important in terms of physical hardening; for example, a site located on the crest of a hill has a good defense position, but its personnel may have difficulty keeping all approach routes under surveillance. On the other hand, hills on one or more sides of a site would provide a sabotage team with advantageous positions for conducting surveillance and for pinning down site defenders with weapons fire.

Communication facilities are located in various places, depending upon their network link. A site located on a military post will require less security than one in an isolated area.

Communication sites also have high visibility, since the large towers and antennas typical of worst sites are visible from a great distance. In many cases, road signs direct the way to the site.

Survivability of the network is also determined by the sites' topography, vegetation, and climate. For example, a heavy forest or dense vegetation may provide excellent cover for saboteurs, but an open field may make a surreptitious attack difficult.

To lower the predicted damage from a hostile attack, each site must add physical improvements to offset any damage that would degrade the communication function. DCA established outage durations that predict the extent of attack success versus various levels of physical security hardness. The basic goal is to add enough physical improvements to lower the predicted damage on any given site.

For example, if a manned site is known to have intrusion sensors and a double fences perimeter, a degrade factor is generated and then applied against the basic probability of success (outage thresholds) from a hostile attack. This analysis yields the level of protection needed in order to maintain the site's communication function.

Restoral/reconstitution after hostile action: As the DCS is degraded by physical or electronic attack, measures will be taken to restore or reconstitute the necessary DCS services.

policy / s o p

The magnitude of the restoral and reconstitution effort must be determined. Once sizing has taken place, types and quantities of equipment necessary can be estimated. Equally important is the availability or need for trained personnel to carry out the restoral or reconstitution effort.

In restoring, the goal is to re-establish critical communications lost or degraded from a hostile attack.

The goal of reconstitution is to restore essential services. The system may be re-established to its original configuration. Reconstitution may include the replacement of damaged or destroyed transmission, switching and control facilities.

The restoral/reconstitution option provides the means to re-establish communications once an outage has occurred. The level of restoral/reconstitution assets needed is directly related to the requirements to be met. It could start with the minimum assets needed to restore critical communications during the first week of conflict and build to the peacetime system configuration or greater as the needs demand. Restoral/reconstitution adds endurance to the system.

The prepositioning option dictates the responsiveness of the restoral/reconstitution option. If no prepositioning is used, the response time is ordering the shipping time from outside the theater. Levels of prepositioning can provide in-theater storage, near site storage or on-site storage. On-site storage provides the greatest responsiveness but requires the greatest amount of capital investment and carries the greatest risk of loss. Prepositioning allows the manager to affect the responsiveness of many restoral/reconstitution actions.

The interconnect option provides a combination of all of the above: interconnects improve the survivability of the system by improving alternate routing capability. Prearranged interconnects provide a restoral/reconstitution option. The method of prearrangement affects responsiveness. Use of interconnects may alter the need for some other options. Interconnects must also consider providing the user alternate routes from his location.

This option requires a degree of judgment in the implementation process. In many cases, destruction of a target DCS site would also mean destruction of the interconnect capability. Interconnects are most useful when--

1. They are physically separate from the site
2. Direct access is available from the user to the interconnect (routing through the DCS site is not required)
3. They can be used to bypass a destroyed DCS site.

policy / s o p

Specific threats for individual DCS sites

Security police and intelligence personnel should be contacted for every specific installation to determine the major threat envisioned at specific locations. Survivability criteria planned should then be approved by intelligence personnel to insure they will be cognizant with threat determination and site projected criticality.

policy / s o p

A SUMMARY OF THREAT CATEGORIES AND MOTIVES

Threat type	Possible threat motivation(s)	Estimated size ranges	Capabilities/training	DCS target type: criticality/location
Vandals (pilferage, theft, break-ins, pranks)	Desire for personal material gain; excitement/amusement/entertainment; possible mental instability or political malcontentment	One, possibly several participants; may be a group in the context of political demonstrations	No special training Hunting arms; heavy, throwable objects (stones, bricks, etc.); assorted small (pocket) objects--knives, wire cutters, etc.	Unmanned or lightly manned; remote or in vicinity of homesteaders or the public
Terrorists	To publicize a cause; psychological effect; anti-American/"imperialist" sentiments	1-10 terrorists	Well-trained, specialization among group members; guerrilla warfare. Equipment/armament: usually small and concealable; may include machine pistols, assault rifles, submachine guns, explosives, hand grenades, smoke bombs, bazookas, mortars, and possibly rockets, mustard gas/nerve agents	Probably manned, high-visibility facility that is very obviously a military (possibly American) installation.
Foreign agents	To threaten DCS operations, facilities, or personnel with damage and/or destruction for the purpose of disrupting DCS operations and/or embarrassing and harassing the U.S. and/or host country	One agent; possibly a small team	Well-trained experts Equipment/armament: small arms (see listing under terrorists), explosives, detonating devices, communications equipment to interface with other operatives and/or "command" center	Critical DCS nodes, unmanned and manned
Special operations forces (SOFs)	Disrupt or destroy DCS operations from peacetime through war by means of unconventional military operations	7-17 men	Highly skilled in sabotage/unconventional warfare Equipment/armament: best available weapons for mission; may include anti-tank guns, snipers' rifles, assault rifles, grenades and launchers, rocket launchers	Critical DCS nodes, unmanned and manned

requirements	criteria	commentary
SABOTAGE THREATS 1. Perimeter security 2. Building penetration resistance	1. a. Full field of visual control around entire site b. Detection of intrusion attempt c. Controlled physical access at perimeter 2. Hardness of building components Penetration resistance is provided by increasing the hardness of the building's components (see "Security Systems") Buildings can have their survivability improved by adding protective surfaces to walls and roofs, eliminating windows, or shielding with glass bricks. In new construction, Kevlar or steel could be installed as subdecking. Buildings should be as low profile as possible, and action such as removal of heat exchangers and ductwork from roofs would contribute greatly to that effort. (89) 3-4 a. Wall construction b. Roof and floor construction c. Perimeter doors d. Windows e. Air vents and ducts f. Locks and builders hardware g. Vaults Cable vaults or power cable heads that are exposed, located near the perimeter, or otherwise vulnerable should be relocated inside the revetted area and the previous location should be obscured. If relocation is impractical, the existing vault should be revetted or placed in a semihardened secured vault. (27) 1-25	

requirements	criteria	commentary
3. Protection of utilities	h. Underground structures To improve physical security, as well as improve the environmental and energy considerations of a new site, underground facilities should always be considered. These underground sites do not always have to be fully hardened sites in the sense that many gains can be obtained through simply building a structure like a partial or full basement and covering the top of the structure with one or more meters of earth. Construction costs for small to medium facilities are not much more than for conventional surface structures, and when other factors such as energy and physical security protection are considered, underground facilities may actually become cheaper. Also, when the level of required structural protection is high (hardened or semihardened), and economics and soil conditions permit, consideration should be given to use of a classical underground structure. Design information is given in Army TM 5-855-1, July 1965. (27) 1-9 3. a. On-site utility components should be given either construction protection or a redundant backup capability. Commercial power is used in normal operation, but it cannot be protected, so on-site backup power must be provided. Electrical power substations should be located at least 50 ft from the inner fence and should be of modular, low-profile design. Transition from the high-voltage transmission line to high-voltage cable should be provided at disconnects within the cleared area outside the perimeter fence. When it is not practical to locate the equipment underground, physically protective enclosures or revetments should be provided. Secondary feeders will be placed in underground ducts or buried steel conduit. (89) 3-4 1. Construction. 2. Redundancy. b. Off-site utility components should be protected. 1. Pumps and wells. 2. Power cables.	

requirements	criteria	commentary
4. Protection of signal cables	4. a. Waveguide routing protection The waveguide transmission lines can be hardened by making them less accessible to intruders and more resistant to damage from small-caliber-weapon fire. They can be hardened by elevating the waveguides, preferably at least 20 ft (6 m) above ground, and enclosing them with a galvanized steel duct. The duct can be in the form of a waveguide bridge extending from the point at which the waveguide first exits the roof of the operations building until it reaches the microwave tower. The duct supports can be secured by fixing them to the tower and the operations building. Ultimately, at the point where the waveguides branch to their separate antennas, the duct can terminate, and individual galvanized steel pipes can be used for hardening. (63) 85 b. Reflector protection Methods for making the reflector less visible should be examined.	
5. Personnel survivability	5. a. Site personnel must have immediate access to their battle gear on-site b. On-site dependents should have safe access to an auxiliary shelter.	

requirements	criteria	commentary
ATTACK THREATS 1. Revetment protection of essential equipment and operations buildings	1. a. Revetment layout design Install revetment around all essential communications facilities (technical equipment, air-conditioning equipment, antenna tower base, and power facilities). To the maximum extent possible, the revetment shall be installed such that a line-of-sight from outside and fenceline does not give a direct view of the essential facilities. New revetted facilities shall meet Class B vault standards. Existing facilities should approach Class B vault standards when economically feasible and appropriate (e.g., windows blocked, doors strengthened). Revetment should be placed as close as possible to facilities being protected but should not interfere with their operation or with that of their associated equipment (e.g., mechanical components). In general, place revetment from 5 ft (1.53 m) to 8 ft (2.44 m) from protected facilities, leaving enough space for removal of bulky items. (27) 1-7 Care shall be taken in placing new revetment on existing facilities to not create excessive soil overburden pressures on existing underground facilities. Consideration shall be given to leaving a vacant area at the main entry to the back-up power facility to allow for movement of generators/power equipment to and from the building. Blast doors in revetment, if used, shall be lockable and alarmed, and shall match the strength of the adjacent revetment. (27) 1-8 Revetment types and construction materials 1. Sandbagging 2. Drum revetment 3. Concrete pipe revetment 4. Reinforced concrete wall revetment 5. Steel bin aircraft revetment 6. Plywood revetment 7. MBA1 landing mat revetment 8. Corrugated metal revetment 9. Massive gravity revetment	

requirements	criteria	commentary
2. Prevention of attack through camouflage techniques	2. a. Camouflage techniques 1. Natural and manmade 2. Hiding and screening b. Coloring materials 1. Asphalt coatings 2. Dope, cellulose acetate butyrate, pigmented camouflage 3. Enamel, alkyd, camouflage 4. Lacquer, camouflage 5. Camouflage by controllable color change 6. Infrared and thermal coatings c. "Tone down" painting d. Decoys 1. Building boards and prefabricated buildings 2. Low-density urethanes e. Natural materials Hydroplanting of vegetation	
3. Obscurants are required at all critical points and capable of remote control at unmanned sites	3. Selection of obscurant materials for various DCS site conditions a. Smoke bomb b. Generator, smoke, mechanical and pulse jet c. Grenade, hand, smoke d. Smoke pots	

requirements	criteria	commentary
4. Antenna and tower protection	4. a. Protective measures Antennas focus microwave energy into a narrow beam for transmission to the next site and collect energy for reception from that site. The antenna consists of a feedhorn terminating the waveguide and a parabolic reflector that forms and redirects the beam. Usually, there is a plastic cover, or radome, over the front of the antenna to protect it from ice and snow. (63) 42 A saboteur who is a marksman might be tempted to shoot holes in the reflector; however, shooting has little effect on the signal, unless the size of the holes is nearly the wavelength of the signal (roughly, the waveguide width). More serious damage can occur if the feedhorn is hit and deformed or moved; however, this would be difficult. (63) 42 1. Antennas 2. Towers 3. Guywires	

requirements	criteria	commentary
5. Fire-port bunkers for personnel	5. a. Site location of bunkers The location of fire-port bunkers is based on the particular site topography, layout of strategic communication buildings, and the type of threat expected. b. Bunker design configuration Bunkers should be designed to accommodate vertical and horizontal "lines-of-fire" and should take site drainage conditions into account. 1. Precast concrete log perimeter bunker 2. Perimeter bunker with offset firing ports 3. Concrete-covered two-man perimeter bunker 4. Rectangular timber frame perimeter bunker 5. Precast concrete panel perimeter bunker 6. Cast-in-place concrete bunker 7. Rating bunkers c. Bunker size and construction materials 1. Precast concrete log perimeter bunker The bunkers are 8 feet 6 inches by 8 feet 6 inches. They are 7 feet 4 inches high and will be constructed of modular reinforced concrete logs. They will have a double-faced 14-gram steel plate access door and three 16- by 42-inch firing ports which can be closed and secured from the inside with hinged one-half-inch thick steel plate covers. 2. Perimeter bunker with offset firing ports 3. Concrete-covered two-man perimeter bunker 4. Rectangular timber frame perimeter bunker 5. Precast concrete panel perimeter bunker 6. Cast-in-place concrete bunker d. Access via trenches The bunkers must be accessible by trenches.	

requirements	criteria	commentary
6. Reconstitution package storage unit	6.a. Site location of units b. Design configurations c. Size and construction materials d. Mechanical/power systems 1. Environmental control systems 2. Power system e. Facility constraints	
7. Protective design	7.a. Protection against direct hits 1. Resistant construction 2. Type of structure - Surface - Buried 3. Protective thickness of materials - Roof design - Wall design 4. Protective floor design 5. Rock-rubble/boulder screens and burster slabs 6. Special design requirements - Working stresses - Reinforcement - Form of structure - Joints - Interior partitions	

requirements	criteria	commentary
8. Hardened transportable equipment	b. Protection against near misses 1. Protective thickness of materials 2. Clear distances 3. Design considerations 8. Design considerations	

requirements	criteria	commentary
CBR THREATS 1. Building resistance and protection	1. a. Exterior surfaces resistant to contamination from agents and decontaminants 1. Continuous skin 2. Resistant finishes b. Openings protected from contamination 1. Air lock entry 2. Waveguide ports 3. Cable ports 4. Power supply entry panels 5. Exhaust pipes (kitchen, etc.) and vent ducts c. Air circulation system Air distribution d. Prevention of HVAC system contamination 1. Automatic dampers and alarms 2. Positive overpressure e. Maintenance of noncontaminated water supplies When DCS facilities have chemical protection, designers should provide emergency water storage and sewage holding for seven days of independent operations. Lines for such systems should have protection from blast pressures and should be contained within structural envelopes. 1. Daily supply 2. Reserve system 3. System survivability 4. Contamination disposal	

requirements	criteria	commentary
2. Decontamination station for personnel protection	2. a. Decontamination station layout design 1. Small decontamination cell 2. Large decontamination cell 3. Portable, collapsible decontamination cell b. Decontamination station construction materials and building items (except for the portable, collapsible type) These materials should be resistant to both chemical contaminants and cleanup processors. 1. Building materials 2. Door hardware 3. Seals 4. Processing control intercom and lighting c. Decontamination station systems A reliable station is necessary to maintain safe environmental conditions. 1. CBR filtering system 2. Air supply/return system 3. Plumbing system 4. Warning and detection system 5. Testing of all systems 6. Updating existing systems 7. Disposition of contaminated or unserviceable filters	

guidance SABOTAGE THREATS/1 Perimeter Security**1. a.** Full field of visual control around entire DCS site (for specific guidance information see SB7, "Security Systems")

1. Use of closed circuit television, manned guard tower, or both
2. Site clearing and grubbing

Native trees serve to improve site camouflage protection from the threat of air attack. However, excessive ground cover decreases site protection by serving as an effective screen for saboteurs or hostile ground troops. Therefore, selective tree removal may be necessary to allow for aerial camouflage while providing a semicleared area at the ground level to observe personnel movement in and around the site. Most of the large trees and some of the small ones should remain in place. However, the lower 8 feet of all trees remaining on site shall be pruned of all limbs. Selective tree clearing and grubbing, tree pruning, and scrub removal should extend over the entire site and to a minimum distance of 30 ft (9.1 m) beyond the perimeter fence. Selective tree and scrub removal shall be done with the assistance and expertise of the site security forces tasked to defend the site (including the host base/command security police function). (27) 1-16

3. Perimeter lighting

Lights located at the inner fence and directed outward will illuminate the perimeter. They should not be directed toward site structures. It may be prudent as an operating procedure to leave the lights turned off and operate them with a manual switch unless they are activated by the IDS when an intruder is present. This practice would avoid illuminating the facility as a target. (89) 3-2

4. Fences

Fences and mesh should prevent grenades and satchel charges from contacting walls and roofs. Everything possible should be placed underground to lower the profile, provide physical protection, and improve EM shielding. (89) 3-2

5. Parking

In general, all areas with possible vehicle parking within 30 ft (9.1 m) of essential facility fences or site perimeter fences and all areas within the essential facility fence shall be designated "No Parking"--existing sites may need to apply a less stringent 15-ft (4.6-m) criteria. (The perimeter fence shall not be construed as the base perimeter fence of a large base or station on which the communications facility may be located.) No vehicles shall be permitted inside essential facility fence except for supply and maintenance vehicles on a very limited basis. No civilian vehicles will be permitted within the essential facility

guidance SABOTAGE THREATS/2 Building Penetration

fence. Parking space and "No Parking" areas shall be designated properly with painted lines. Painted lines shall be a low-light-reflecting (tonedown) color. All facilities shall be planned with parking areas located outside the site perimeter fence, and preferably with tree cover to reduce target acquisition by aerial attack. However, some exceptions will be required at existing facilities due to their site conditions. Those exceptions will be reviewed on a case-by-case basis by command civil engineering, communications-electronics, and security police personnel.

b. Detection of any intrusion attempts (for specific guidance information see SB7--"Security Systems")

1. Access road sensors
2. Fence disturbance sensors
3. Ground disturbance sensors
4. Building and equipment protection sensors

c. Controlled physical access of perimeter**2.** Hardness of building components (for specific guidance information see SB7, "Security Systems")

- a. Wall construction
- b. Roof and floor construction
- c. Perimeter doors
- d. Windows
- e. Air vents and ducts
- f. Locks and builders hardware
- g. Vaults
- h. Concept of five-zone "depth in defense"

Each zone has a different goal: zone 0, improved observation; zone 1, deterrence; zone 2, deterrence and detection; zone 3, detection and delay; and zone 4, delay and apprehension.

a. Zone 0: The region outside the perimeter

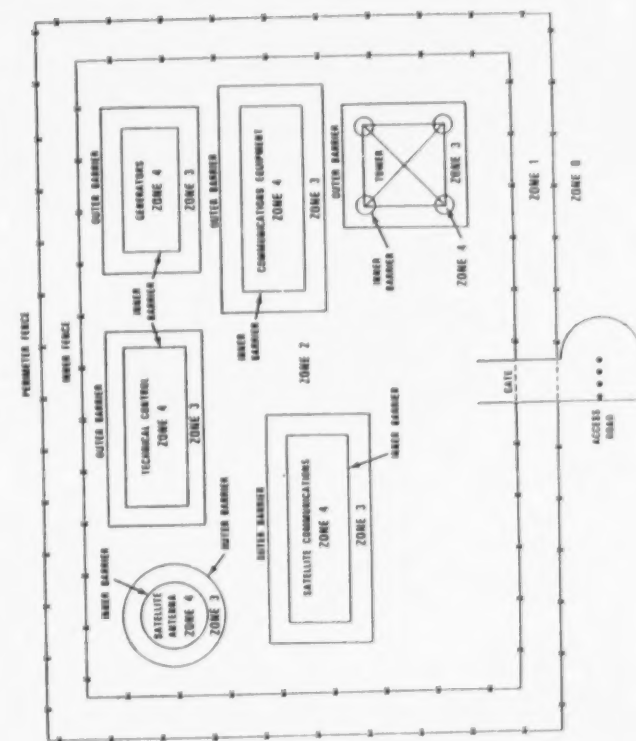
1. Cleared land
2. Access road
3. Parking lots

guidance SABOTAGE THREATS/2 Building Penetration

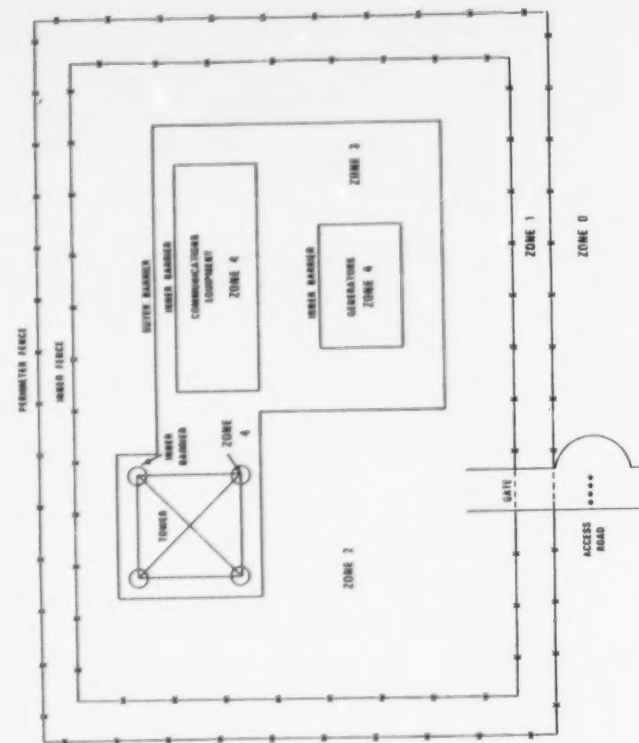
4. Commercial power lines
5. Guy wires
- b. Zone 1: The perimeter fence and the region between the perimeter and inner fences
 1. Perimeter fence, gate, locks
 2. Cleared area between perimeter and inner fence
 3. Warning signs
 4. Sensors
- c. Zone 2: The inner fence and the area between the inner fence and the outer barriers needed to protect towers, antennas, power sources, and electronic equipment
 1. Inner fence, gates, locks
 2. Sensors on the inner fence
 3. Perimeter lighting
 4. Closed circuit television
 5. Communication cables
 6. Fuel storage
 7. Fuel lines
 8. Air-conditioning
- d. Zone 3: The outer barriers and the area between the outer barriers and the inner barriers needed to protect towers, antennas, power sources, and electronic equipment
 1. Outer barriers (walls)
 2. Area between the outer and inner barriers
 3. Wave guides
 4. Antennas and antenna feeds
- e. Zone 4: The inner barriers needed to protect towers, antennas, power and fuel sources, and electronic equipment, and the area within the inner barriers
 1. Inner barriers
 2. Area within the inner barriers

guidance SABOTAGE THREATS/2 Building Penetration

3. Towers and tower legs
4. Guy wires and guy wire anchors
5. Electronic equipment
6. Power and fuel sources



EXAMPLE OF SECURITY ZONES FOR A GENERIC MANNED DCS SITE

guidance **SABOTAGE THREATS/3** Utilities Protection

EXAMPLE OF SECURITY ZONES FOR A GENERIC UNMANNED DCS SITE.

3. a. On-site utility components should be protected.

1. Protection by construction

a. Fuel storage--Fuel storage tanks and fuel lines for back-up generators shall be constructed underground when possible. However, above-ground placement may be required when ground conditions (solid rock) prohibit buried installation, or when buried installation would be cost-prohibitive. When above-ground tanks are used, they shall be revetted. Careful consideration for explosion hazards shall be given before locating fuel tanks within revetted areas that enclose other facilities. New above-ground tanks within the revetted area shall be located no closer than 20 ft (6.1 m) to technical or back-up facility. Storage tanks shall be lockable. (27) 1-20

guidance **SABOTAGE THREATS/3** Utilities Protection

Fuel tanks should not be placed such that gravity flow will spill fuel into the operations building or any other site components. Day tanks should not be placed inside a building where they could become fire hazards if ruptured or overheated. They should be placed underground or should have the same protection as the main fuel tanks. Storage of oil and volatiles in containers other than protected tanks will be minimized and will not, as a rule, be permitted inside buildings or in locations that invite vandalism or sabotage.

(89) 3-6

Fuel-tank filler pipes should be equipped with access caps that can be locked in place. An unlocked cap allows abrasive or corrosive agents to reach to the fuel. (63) 49

b. Water supply--To secure the conventional water supply system, items to be considered are: fencing around off-site pump and well site with intrusion detection devices around the fence and intrusion alarm on the gate; lock all access ports to valves and open water areas; lock all doors securely and block in all windows to pump/chlorination buildings; and apply Class B vault construction standards for new pumphouse and associated facilities. (27) 1-23

c. Emergency water supply--Install the underground emergency water supply tank at least 10 ft (3.05 m) within the essential facility fenceline. This tank must be lockable. Controls on the water distribution system must be such that this supply is not depleted under normal conditions. However, emergency water must be integral with the normal system's water flow for periodic replacement of stored water with fresh water. Controls should then be added to enable use of this water reserve under emergencies. Unless more stringent criteria exist, storage capacity should be 20 gallons (75.7 liters) per capita per day for 7 days. The user population should be the total DCS station complement during an emergency situation. It must be possible to isolate this supply from other water sources. The requirement for separate emergency water storage tank may be ignored if the existing supply can be shown to be adequate at all times and can be protected economically. (See SB1 - "Water Supply Impact.") (127) 1-11

d. Power lines--Commercial power lines, which service most sites, can be hardened by reducing their accessibility if the transmission method continues without change until the lines enter the equipment building. For example, underground cables should remain buried until entering the equipment building beneath its foundation. Overhead lines should remain parallel to the ground until entering the equipment building. (63) 89

Place all on-site power and communications cables at least 3 feet (0.91 meters) underground. Obscure the locations of critical underground power and communications lines to prevent detection of location by saboteurs. Consider burying

guidance SABOTAGE THREATS/4 Signal Cable Protect.

commercial power lines to a distance 1969 feet (600 meters) from the site. Cables should enter and exit the site through diverse routes when practical so that all communications are not severed should a single cable be cut. (27) 1-21

e. Transformer--Consideration shall be given to placing the power transformer inside the revetted area on concrete pads (not pole-mounted). (27) 1-21

2. Redundant backup capability

Provide redundant power cable to critical functions.

Off-site utility components should be protected

1. Protect off-site water system pump and walls

2. Bury off-site power cables from commercial power supply sources:

All cables must be buried 3 feet for a distance of 600 meters (approximately 2000 feet) from the site boundary.

Locations should be obscure.

All manholes and cable vaults shall be locked.

4. a. Waveguide routing protection

Waveguides are normally routed from the communications building to the tower and up to the reflector and horns. In many cases, waveguides are routed to horns at a relatively low level and close to the ground; a microwave is beamed at the top of the tower, where only the reflector is located. Most waveguides are exposed, easily accessible, and provide very lucrative targets. Damage to the waveguides is accomplished easily by cutting, pinching, or shooting small arms from outside the fence, or by a simple explosive. The waveguide system can be repaired in 3 to 4 hours if repair parts are available. However, multiple areas of damage, adverse weather conditions (such as high winds or freezing temperatures) and damage high up on the tower would lengthen the repair time of a waveguide system.

Most waveguides are supported by a metal structure running from the equipment building to the tower. This bridge may keep the waveguides far enough above ground to prevent attack. A waveguide bridge is judged accessible and susceptible when the waveguides are less than 10 ft (3 m) above ground. (63) 41

RF transmission, power, and control lines on exposed towers should be protected from small-arms fire by means such as steel or Kevlar armor plate deflectors or by enclosure in heavy steel conduit or Kevlar tubing. Present designs place the antenna reflector and feedhorn near maximum available heights on antenna

guidance SABOTAGE THREATS/5 Personnel Survivability

towers. These are the most visible parts of the installation and are highly vulnerable to attack by saboteurs. Waveguide runs should be underground if this is not prevented by factors such as surface rock or high water tables. In any event, they should be low profile and protected by Kevlar or steel armor plate if located above ground. The waveguide bridge must be protected similarly, since the waveguide's integrity is tied directly to bridge survivability. (89) 3-4

b. Reflector protection

Protective measures should also be taken to prevent small arms fire damage to reflectors and horns by covering antennas with radomes. This will limit freehorn visibility and access. Installation of microwave antenna shrouds will increase protection.

5. a. Site personnel must have immediate access to their battle gear on-site.

The facility protection countermeasures cited above will help protect personnel. Other measures include wearing helmets, flak vests, gas masks, or other protective clothing. At overseas locations, small arms, helmets, and other necessary equipment should be stored on-site for immediate use if necessary.

b. On-site dependents should have safe access to an auxiliary shelter

The safety of dependents should neither be neglected nor should it distract personnel from their military duty. Establishment of a fully equipped, self-contained shelter for off-duty personnel and families should be considered, especially in contingency plans. Consideration should also be given to establishing a constant level of essential supplies such as fuels, food, water, and emergency medical supplies.

ATTACK THREATS

1. Revetment layout design

1. Revetments and protective walls

Revetments may be constructed of various resistant materials of thicknesses conforming to those given in the following three tables. Revetments should be resistant to blast as well as bomb fragments. Therefore, they must be inherently stable against overturning and must incorporate continuity to resist shattering or disintegration. Certain construction features are thus essential, including (1) proof thickness from perforation by bomb fragments to meet the required standard of protection, (2) stability of the wall to resist overturning by blast, and (3) adequate reinforcing or bonding to prevent the wall from disintegrating.

guidance ATTACK THREATS/1 Revetments

The enemy will use numerous conventional weapons to attack, including small arms, grenades and mortars, demolition charges, rockets, artillery, fire/incendiary, shaped-charges, and bombs. Generally, USAFE protective construction is designed using the 500- and 1000-pound general purpose bombs as governing threats. Perimeter defense firing points usable only during ground-to-ground operations are an exception. These should be designed for other more probable, but less severe, weapons effects considering local tactical threat situations. (27) 2-1

For large general purpose bombs, air blast effects decline rapidly with distance of a facility from the detonation point (effective miss distance, EMD). Accordingly, as the miss distance increases beyond approximately 30 feet, so does the feasibility of protecting with revetments instead of complete sheltering. A revetment offers almost no protection against a direct hit because of its open top; however, a high level of protection can be provided personnel and equipment against near misses--and at greatly reduced construction costs. (27) 2-1

Revetments can provide the level of protection required by most facilities and at far less cost than total sheltering. Though they do not provide a high enough probability of survival for critical operational elements, revetments are quite adequate as permanent protection for many important facilities and, in all cases, are vastly superior to having no protection. (27) 2-1

Facility designs (revetment and bunker) depend on several factors: functional prioritization, damage expectancy, construction capability, cost, and siting constraints. Construction capability includes equipment, materials, and personnel with the necessary skills and is a particularly important factor regarding self-help projects. Facility design must (1) minimize equipment demands, (2) maximize participation of semiskilled personnel, (3) allow incremental construction (fluctuating rate of material and manpower input), and (4) permit innovative use of various types of surplus materials. (27) 2-1

Several standard revetment designs have been constructed and evaluated by 86 TFW personnel at Ramstein AB. The objectives of this 1976 program were to establish design applicability to "self-help" construction measures, optimize design/construction procedures, establish construction planning factors and provide other bases with validated design options. Results of this program were published in a January 1976 report entitled "Project CREEK PROTECT Prototype Revetment Construction Study." (Reference 28) (27) 2-2

guidance ATTACK THREATS/1 Revetments**1. a. Revetment types and construction materials**

Revetments primarily protect against small arms fire, near-miss blasts, and minimum direct hits, thus significantly adding to the "hardness" of the facility. Selection of a system will depend upon such factors as availability of materials, cost, construction effort, repair effort, flexibility of design, permanence, degree of threat, and protection provided.

1. Sandbag revetment

This technique is best used to enclose small areas, such as auxiliary power units and fuel tanks, especially when conditions warrant quick protection. A sandbag revetment has one vertical face, which allows it to be placed closer to the object being protected. The vertical face can be constructed using aircraft revetment or other suitable material. This face is maintained by using tie-wires connected to blocking boards on the opposite face of the revetment. The sandbags should be filled with a dry sand/cement mixture, which will double the revetment's life expectancy. The final step is to tone down any visually outstanding features of the revetment. (27) 2-3

Construction procedures (28) 3-19

- a. Survey the site. No excavation permit is required since this revetment type does not call for a footing.
- b. Begin planning and acquire materials.
- c. Layout field.
- d. Preposition sand and cement.
- e. Dry mix sand and cement (4 to 1) using a portable cement mixer.
- f. Fill sandbags from mixer.
- g. Place sandbags sloping on one side.
- h. Secure the vertical wall using metal revetment material. The material is held in position by tie bars connected to holding blocks on the opposite face of the revetment.
- i. Clean site.

guidance ATTACK THREATS/1 Revetments

Potential construction problems (28) 3-19

(None.)

Recommendations (28) 3-19

(None.)

2. Sand-filled drum revetment

This consists of two offset rows of 55-gallon drums stacked two-high. The initial step is construction of an 8-inch concrete foundation. The drums are cleaned thoroughly and painted both inside and out with a rust inhibiting compound. This process greatly increases the revetment's life and reduces maintenance needs. (27) 2-2

Drum revetment effectiveness is markedly increased if the drums are joined structurally such that (1) in the transverse plane, they either slide or rotate as a single rigid body and (2) the revetment is capable of beam action in the longitudinal direction. (27) 2-2

The first level of the drums is placed and filled with sand to within 8 inches of the top. Holes are then punched between each adjacent drum 4 inches from the top and a 1-inch diameter rebar section is inserted. Next, a concrete cap is placed, allowing the steel reinforcement bars to tie the drums together so the revetment can function more as a unit. The same process is repeated for the top level. Vertical doweling placed similarly also is advisable. Concrete capping prevents the soil fill from becoming wet and losing as much as one-half its penetration resistance. The final step is to tone down the revetment. (27) 2-3

Construction procedures (28) 3-15

- a. Survey the site and obtain an excavation permit.
- b. Begin planning and requisition materials.
- c. Lay out field.
- d. Excavate for footing.
- e. Have drum delivered.
- f. Cut the tops out of the drums.

guidance ATTACK THREATS/1 Revetments

g. Place the forms for the footing and the tempered steel.

h. Place the concrete footing. The concrete should be given a brush finish to reduce drum elements' sliding potential.

i. Coat the insides of each drum with a bituminous compound. Also give a bituminous coating to the area of each drum that will be inside the revetment.

j. Place the first level of drums on the footing.

k. Fill the drums with sand.

l. Cut the rebar ties.

m. Cut holes between adjacent drums and insert the tie bars.

n. Cap the first level of drums with concrete poured directly from the transit mix truck.

o. While the concrete cap is still wet, set one rebar vertically into the concrete extending 6 inches above the top of the drum. This is done for every third or fourth drum.

p. Place the second level of drums. On the third or fourth drum (see a above), install the top drum on the vertical rebar extending from the cap on the first level drum.

q. Fill the second-level drum with sand.

r. Cut holes between adjacent drums and insert the tie bars.

s. Cap the second level of drums with concrete. This may be done by hand shoveling from the bucket of a front-end loader.

t. Sandblast the exposed part of the erected revetment.

u. Prime the prepared revetment surface and give it a toredown treatment to match the building.

v. Clean the site.

Potential construction problems (28) 3-16

- a. Capping the drums on the second level from a front-end loader is very time consuming and laborious.

guidance ATTACK THREATS/1 Revetments

- b. Cutting the tops from the drums with a hammer and chisel also is time consuming.
- c. The method used for preparing the drums in this program may prove unsatisfactory.

Recommendations (28) 3-16

- a. Consider leasing a concrete pump for capping the second level of drums.
- b. Develop an alternative, less time consuming procedure for removing the drum tops.
- c. The drums must be treated before placement in the revetment. Treatment must include thorough cleaning and sandblasting to remove rust, and the inside and bottom must be given a thorough coat of bituminous paint. The exterior must be properly primed. After erection, all damaged areas must be touched up. Proper preparation is essential or this revetment type's life and lifetime maintenance costs will make its use of questionable merit, despite lower initial costs.

3. Sand-filled concrete pipe revetment

This revetment contains two offset rows of vertical concrete culvert pipe. The culvert should be at least 6 feet high with a 2-foot diameter. The initial step is construction of an 8-inch concrete foundation to provide the necessary support as well as a level surface on which to set the culvert. The culvert sections are set in place with a forklift and filled with sand to within 10 inches of the top. Connectors made of 1-inch rebar are placed diagonally between culvert sections. When the concrete cap is placed, these connectors tie the culverts together, making the revetment function as a unit. After cap placement, the revetment is toned down. The concrete cap also keeps the sand fill dry to prevent its losing as much as one-half its resistance to penetration. (27) 2-3

Construction procedures (28) 3-11

- a. Survey the site and obtain an excavation permit.
- b. Begin planning and requisition materials.
- c. Lay out field.
- d. Excavate for footing.
- e. Place forms for the footing and the tempered steel.

guidance ATTACK THREATS/1 Revetments

- f. Place the concrete footing.
- g. Position the concrete culvert pipes using a front-end loader.
- h. Fill the culvert pipes with sand. This can be done by hand-shoveling the sand from the bed of a dump truck.
- i. Cut and form the rebar ties.
- j. Place the diagonal tie bars.
- k. Cap the culvert pipes with concrete. The concrete can be lifted to the top of the culvert pipe with a front-end loader and shoveled into place.
- l. Make removable culverts by inverting hairpin-shaped sections of rebar flared at the ends into the culverts. The bottom of the culverts should be plugged with concrete to help anchor the rebar and prevent sand spillage when culvert pipes are repositioned later. The culverts should then be filled with sand and capped with concrete. The looped end of the rebar extends above the culvert as a lifting piece.
- m. Give the completed revetment a tone-down treatment to match the building.
- n. Clean the site.

Potential construction problems (28) 3-12

- a. Cutting and shaping the diagonal tie-bars may require an excessive number of manhours.
- b. Hand shoveling the concrete from the bucket of a front-end loader into the culverts for the concrete cap can be extremely slow. It requires the transit mix truck to remain on-site for long periods of time. The contractor's waiting time may be critical.

Recommendations (28) 3-12

- a. Purchase the diagonal tie bars precut and preformed.
- b. Consider leasing a concrete pump for capping the culverts. This would greatly reduce the manhours required as well as the contractor's waiting time.
- c. Investigate another way to provide removable sections. There is no real difficulty in the method used in this program, but a less complicated method might be found.

guidance ATTACK THREATS/1 Revetments

- d. Investigate the use of a different culvert cross sectional design. Using a rectangular shape would reduce the number of culvert sections by 50 percent.

4. Reinforced concrete revetment

This revetment design consists of either precast or cast-in-place reinforced concrete. The precast approach was selected for prototyping as it was considered more applicable to self-help and allowed remote fabrication. The initial step is to excavate below the frost line. After excavation, forms for U-shaped support blocks are set to grade and concrete is placed. Concurrently, at a separate site, forms for the vertical panels are made, reinforcing steel is placed, and concrete is poured. At Ramstein AB, the panels were made horizontally inside an aircraft maintenance shelter using the floor slab as part of the formwork. Lifting hooks were included. After curing, the concrete panels were taken to the construction site and placed upright in the support blocks. The foundation steel is then placed and the concrete foundation is poured. After the foundation has cured, the remaining excavation is backfilled and cracks between the panels are grouted. The final step is to tone down the revetment. (27) 2-2

Construction procedures (28) 3-3

- a. Survey the site and obtain an excavation permit.
- b. Begin planning and requisition materials.
- c. Lay out field.
- d. Excavate for footing.
- e. Prefabricate the setting block forms.
- f. Cut rebar to size for the setting blocks.
- g. Set block forms and rebar.
- h. Place concrete in the setting block forms and vibrate during placement.
- i. Prefabricate wall panel forms.
- j. Cut rebar to size for the wall panels.
- k. Place rebar inside wall panel form and include lifting points if they are determined necessary. Form keyways into each panel for adjacent panel alignment.
- l. Place concrete in wall panel forms. A vibrator and

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probe sticks can be used to consolidate and insure proper concrete distribution.

- m. Place concrete wall panels on the setting blocks. Some type of crane will be necessary.
- n. Cut rebar size for the grade beam.
- o. Place grade beam rebar.
- p. Place hardwood blocks into keyways to align the wall panels accurately, or if a tongue-and-groove keyway is used, simply align wall panels.
- q. Place concrete for the grade beam.
- r. Grout joints between the wall panels.
- s. Provide tone down treatment for the finished wall.
- t. Clean the site.

Potential construction problems (28) 3-4

- a. If lifting points are used, care must be taken in their design and in lifting the wall panel. If lifting points are not used, a two-cable sling and guideline can be used successfully.
- b. The rebar protruding from the setting blocks may require excessive bending and rebending when setting the wall panels.
- c. The wooden forms used for the wall panels may not be salvageable for reuse.

Recommendations (28) 3-4

- a. Consider local conditions and skills available at each site in deciding whether to use precast or cast-in-place construction. The precast approach may be more flexible and may reduce interference with routine operations at the site.
- b. Investigate a design modification to allow wall panels to be cast monolithically with the setting blocks. Insure desired elevations of the precast units by placing them on a previously constructed concrete footing slab. These wall sections would then be tied together by a steel reinforced grade beam poured on-site between the setting blocks. Good anchorage of wall section reinforcing steel into the grade beam is essential.

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- c. Forms should be made of steel and perhaps rotated between bases installing this type of revetment.
- d. Purchase all rebar precut to eliminate a sizable amount of labor at moderate additional costs.

5. Steel bin aircraft revetment

This is a modified metal aircraft revetment filled with sand. The initial step is construction of an 8-inch concrete foundation to provide the necessary support as well as a level surface for placing the revetment. Nominal height of this revetment is 8 feet, but this can be modified to suit individual revetment needs. The cross member sections are modified to provide a revetment width of 4 feet. After revetment sections are put together, the bins are filled to within 6 inches of the top. The revetment is then capped with concrete and toned down. (27) 2-3

Construction procedures (28) 3-8

- a. Survey the site and obtain an excavation permit.
- b. Begin planning and requisition materials.
- c. Lay out field.
- d. Excavate for footing.
- e. Place forms for the footing and the tempered steel.
- f. Place the concrete footing. Give the concrete a brush finish to increase resistance to wall panel sliding under dynamic loading.
- g. Erect the lower horizontal section of revetment (3 feet high) in accordance with the manufacturer's instructions.
- h. Fill the first 3-foot section with sand. The bins can be filled using a front-end loader.
- i. Erect the remaining revetment sections. The initial 3-foot section will provide an interior working platform.
- j. Fill the remaining revetment sections with sand.
- k. Place the concrete cap on the completed revetment. A front-end loader can be used to lift the concrete.
- l. Clean the site.

guidance ATTACK THREATS/1 Revetments**Potential construction problems**

Make sure a flaring tool is provided in the erection kit.

Recommendations

- a. Consider leasing a concrete pump for placing the concrete cap faster.
- b. This revetment type is extremely simple to erect and is very useful in self-help programs. It should be used in this program to the greatest extent possible.

6. Plywood revetment

The supporting system consists of 6-by-12-inch timber posts embedded in concrete to a depth of 3 feet. The posts are spaced 4 feet apart and covered with layers of 3/4 inch thick sheets of exterior grade plywood. Bolts 1/2 inch in diameter and 24 inches long pass through 4-by-4-foot horizontal braces. Horizontal braces are placed at top and bottom and 30 inches apart in between. (146) p. 16

The effectiveness of various plywood thicknesses against fragment penetration (three rounds detonated at 30 feet) is shown in the following table. It is assumed that the plywood revetment is not filled with soil. If filled with soil, the revetment will be 100 percent effective for all thicknesses at a distance of 5 feet. (131) 32 (147) 34

PERCENT EFFECTIVENESS

Threat	3/4" Plywood	1-1/2" Plywood	2-1/4" Plywood
81-mm mortar	60	82	91
82-mm mortar	64	86	97 N
4.2-in. mortar	24	55	71 M
107-mm rocket	47	71	86 M
120-mm mortar	60	84	91 N
122-mm rocket	--	--	--

7. M8A1 landing mat revetment

Supported by timber posts--Six-by-12-inch timber posts are embedded in concrete to a depth of 2 feet. The posts are placed on center. After the posts are set, 12-foot long pieces of mat are laid adjacent to each side of the revetment and locked together to the desired height. Pre-drilled holes, 7/16 inch in diameter, are centered two over each mat unit into a 2 inch steel angle. This hole spacing is transferred to the mat, where holes are burned. Sections are lifted into place with a crane. Sections are secured with 3/8-inch

guidance ATTACK THREATS/1 Revetments

diameter bolts, 17 inches long. These bolts will pass through the angle and mat on one side to the same in the other. Bolts must be located so as not to pass through timber posts. The assembly is filled with loose, clayey sand using a scoop loader. (147) 15

Supported by pipe posts--Pipes 3 inches in diameter and 6 feet long are embedded in concrete to a depth of 5 feet. Mat sections are lifted into place with a crane. Weld sections are tacked to the inside portion of pipe posts as the crane holds them in place. Sections must be lapped and tack welded at vertical joints. The assembly is then filled with soil. (147) 16

The effectiveness of various mat lengths against fragment penetration is shown below. Values are for nonfilled assemblies. If filled with soil, all sizes will be 100 percent effective against all threats shown. (131) 33, (147) 34

Threat	PERCENT EFFECTIVENESS			
		5' Mat	10' Mat	20' Mat30' Mat
81-mm mortar	95 N	98	98-100	98-100
82-mm mortar	98 N	98-100	98-100	98-100
4.2-in. mortar	76 N	82	91	98
107-mm rocket	70 N	79	89	96
120-mm mortar	98 N	98-100	98-100	98-100
122-mm rocket	-- M	--	70	78

8. Corrugated metal revetment

Corrugated metal revetments are identical to the plywood structure except that part is covered with 26-gage corrugated metal siding instead of plywood. Also, posts are set 5 feet in the ground without concrete. The horizontal bearing area of the 6-by-12-inch timber posts is increased by attaching 2-by-12-inch lumber to both 6-inch dimensions of each post. This attachment extends from the ground surface to the bottom of the post. The assembly is then filled with soil. (147) 17

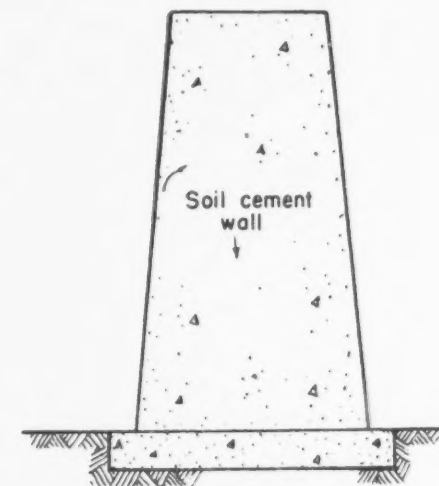
There is 100 percent effectiveness against fragment penetration at 5 feet for all rounds. However, moderate structural damage occurred from the 120-millimeter mortar and severe damage from the 107-millimeter rocket and the 4.2-inch mortar.

Each completed revetment should be capped with a waterproof material to minimize moisture content. Sandbags, membrane, asphalt, concrete, and roofing paper are suitable.

guidance ATTACK THREATS/1 Revetments

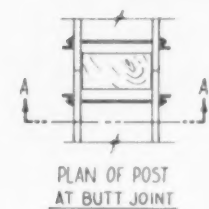
9. Massive gravity walls

These walls are suitable where space is available. They are not as economical in materials as the structurally supported types and must be well bonded or substantially framed. Earth-filled timber cribs are economical for exterior protection when coordinated with excavation work. Bitudobe brick is suitable where the climate allows it to be used.

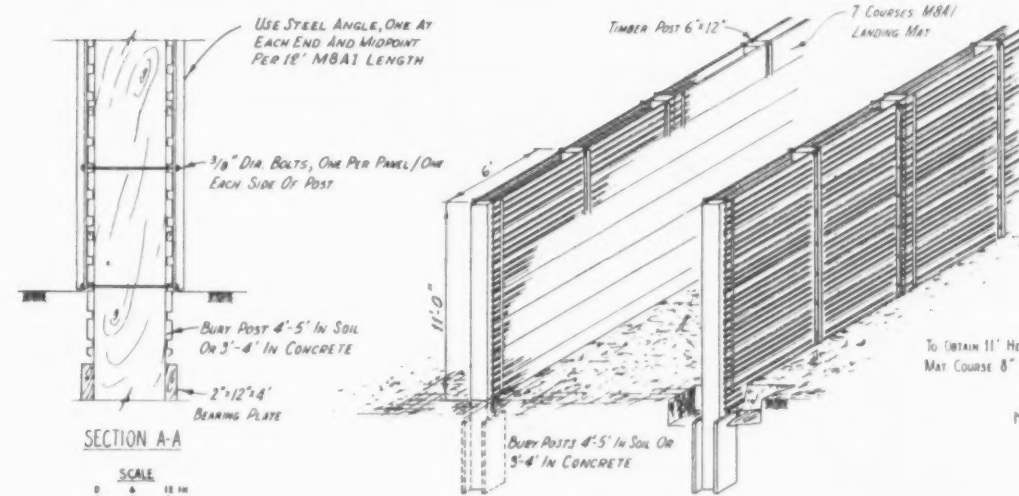


MASSIVE GRAVITY WALL

guidance ATTACK THREATS/1 Revetments



MATERIALS LIST	
ITEM	NO. REQUIRED
6" x 12" x 16' TIMBER POST	38
MBA1 LANDING MAT	17 BUNDLES
3/8" x 17" LG. BOLTS w/ WASHERS	364
2" x 2" x 1/4" STEEL ANGLE 11' LG.	104
2" x 12" x 8' TIMBER BEARING PLATE	38



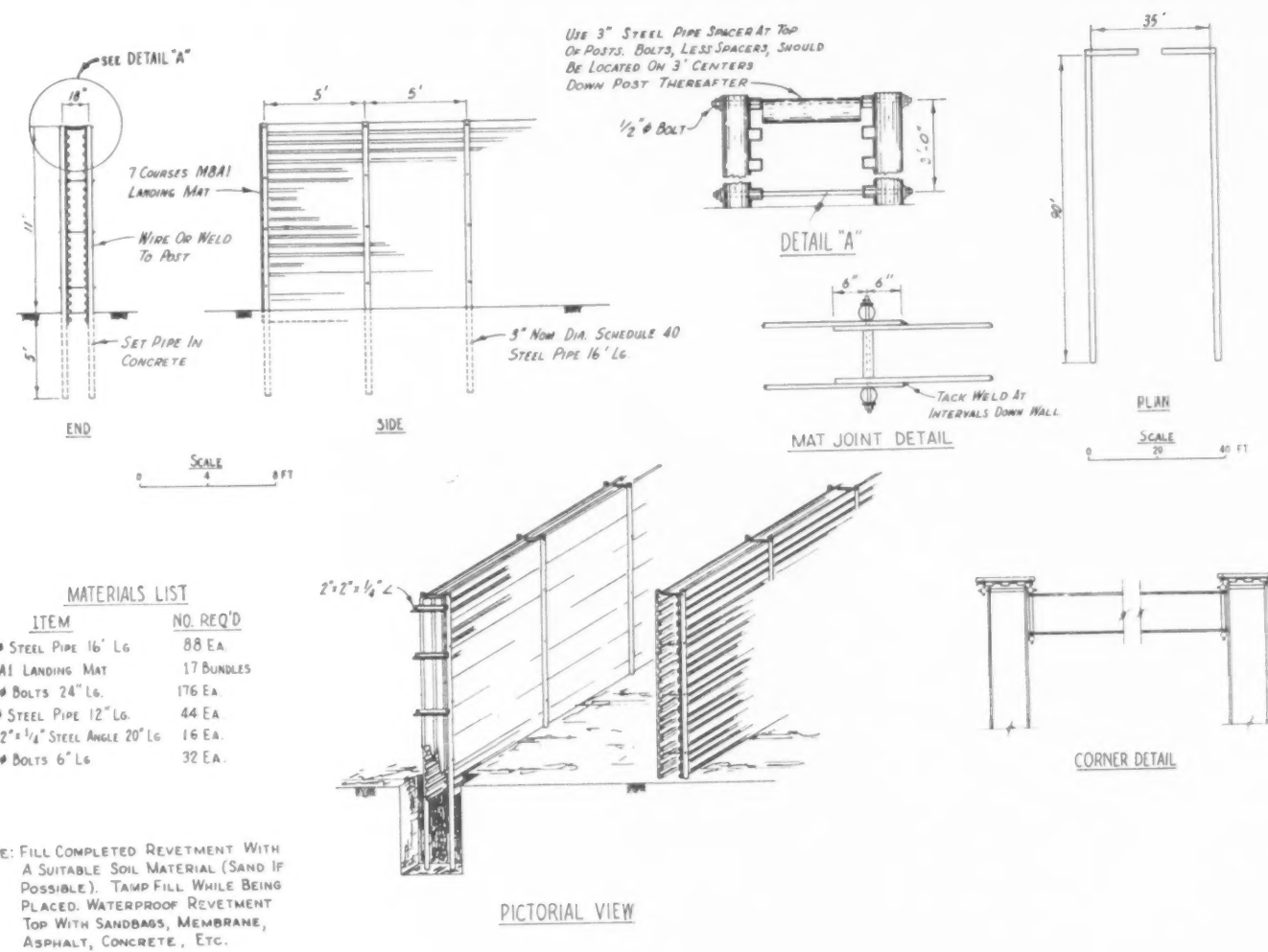
TO OBTAIN 11' HEIGHT START FIRST
MAT COURSE 8" IN THE GROUND

NOTE: FILL COMPLETED REVETMENT WITH
A SUITABLE SOIL MATERIAL (SAND IF
POSSIBLE). TAMP FILL WHILE BEING
PLACED. WATERPROOF REVETMENT
TOP WITH SANDBAGS, MEMBRANE,
ASPHALT, CONCRETE, ETC.

PICTORIAL VIEW

MBA1 LANDING MAT SOIL-FILLED REVETMENT TIMBER POSTS.

guidance ATTACK THREATS/1 Revetments



M8A1 LANDING MAT SOIL-FILLED REVETMENT PIPE POSTS.

guidance **ATTACK THREATS/1 Revetments**

REQUIRED THICKNESSES OF MATERIALS TO PROTECT AGAINST FRAGMENTS AND
BOMB BLASTS OF ALL TYPES AT A DISTANCE OF 40 FEET (IN INCHES) (184) 4-8

Bomb	Mild steel	Reinforced concrete	Plain concrete	Reinforced brickwork	Plain brickwork	Precast concrete block	Earth-filled crib	Sandbags
100-pound	1	10	14	13-1/2	13-1/2	16	20	24
250-pound	1-1/2	12	16	13-1/2	17	20	24	30
500-pound	2	12	18	17	21-1/2	24	30	36
1,000-pound	2-1/2	16	22	21-1/2	25	28	36	42
2,000-pound	3	20	28	25	28-1/2	32	42	54

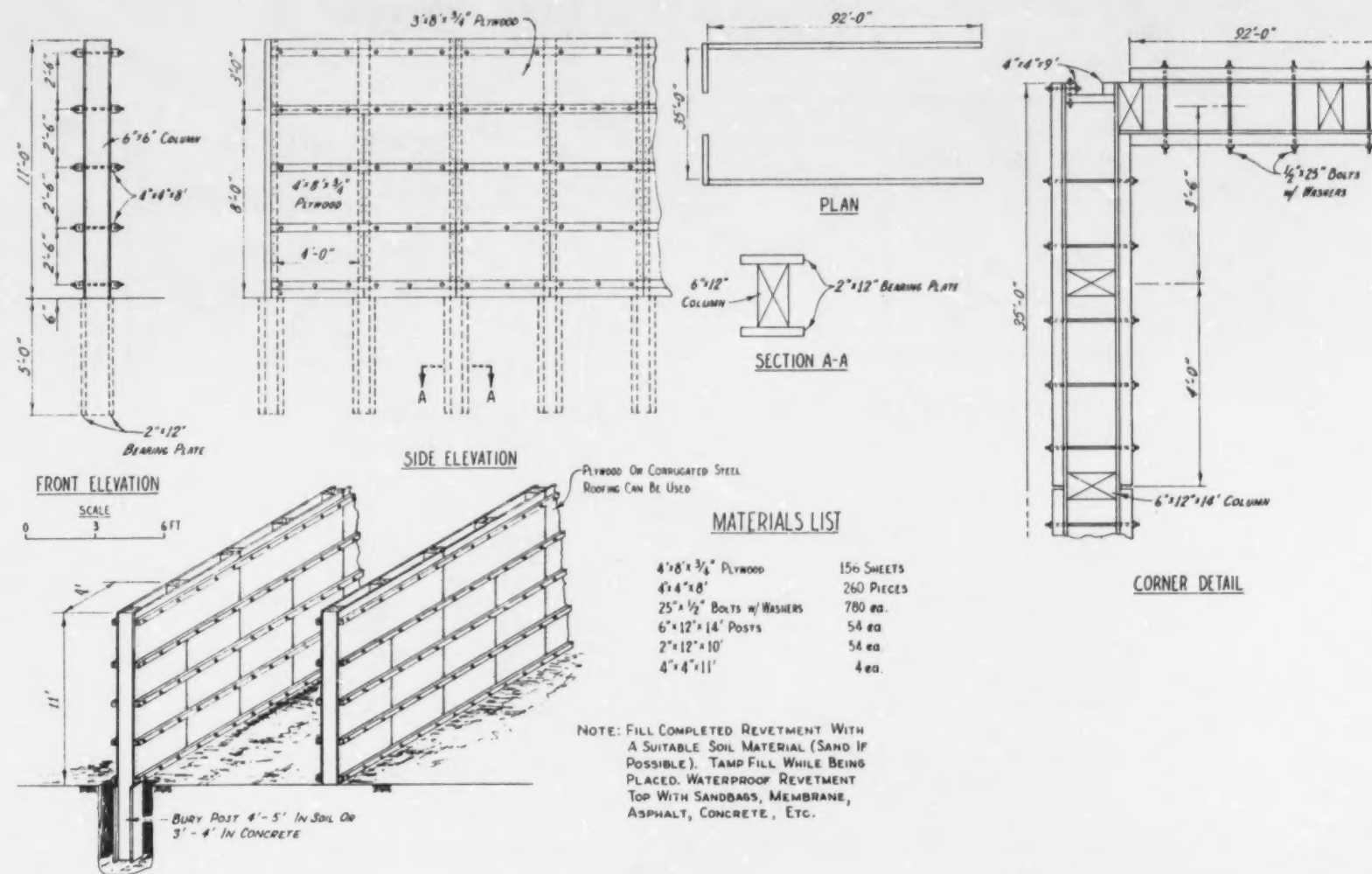
ESTIMATED THICKNESSES REQUIRED TO PROTECT AGAINST FRAGMENTS
OF BOMBS EXPLODING AT A DISTANCE OF 25 FEET (IN INCHES) (184) 3-51

Bomb	Mild steel	Reinforced concrete	Brickwork	Sand
110-pound	1	10	12	30
220-pound	1-1/2	14	15	--
550-pound	2-1/2	16	17	48
1100-pound	3	18	20	--
2200-pound	3-1/2	21	25	54

ESTIMATED THICKNESSES REQUIRED TO PROTECT AGAINST FRAGMENTS
DUE TO SHELLS EXPLODING NEARBY (184) 3-51

Shell	Mild steel	Reinforced concrete	Brickwork
20-mm	1/4	3	4
40-mm	1/2	6	8
105-mm	1-1/4	15	17
155-mm	1-3/4	21	24

guidance ATTACK THREATS/1 Revetments



READY
FIGURE

guidance ATTACK THREATS/2 Camouflage**2. a. Camouflage techniques**

Camouflage is a concealment technique. When used correctly, it will minimize the vulnerability of a fixed installation. The main concealment methods are:

Hiding--Obstructing a sensor's field of view with natural terrain or foliage

Masking--Obstructing a sensor's field of view with artificial cover, such as a net

Blending--Matching the reflectance characteristics of an object with its background

Disruption--Eliminating or changing distinct object patterns

Disguise--Giving a sensor a false impression about an object

Distraction--Focusing an enemy's attention away from an object

Decoying--Providing an effective fake object

This guide deals with four similar techniques--hiding, blending, disguise, and decoying. (145) 13

1. Natural and manmade

Camouflage materials can be divided into two main categories: natural and manmade. Natural materials, indigenous to an area, can be divided into four groups:

Growing (cut or planted)

Cut and dead vegetation

Inert substances of the earth

Debris

Manmade materials can be divided into three categories:

Hiding and screening materials, such as prefabricated nets, net sets, flattops, burlap, asnaburg, small mesh nets and wire netting, snow fencing, trucks, tarpaulin, and smoke

Garnishing and texturing materials, such as gravel, cinders, sawdust, fabric strips, feathers, and Spanish moss

Coloring materials, including all exterior "tone-down" painting. (146) 381-383

guidance ATTACK THREATS/2 Camouflage**2. Hiding and screening**

Hiding and screening materials should be used to supplement a camouflage program.

Camouflage screening system (modular lightweight synthetic)

Primary operative mode--screening

Secondary operative mode--blending, disguise, decoying

Threat avoidance capability--ultraviolet, visible, near infrared, and rods

This is one of the best techniques available for the concealment of fixed installations using artificial material, especially for desert or woodland conditions. The screening system is a stock item available from DODISS (145) B-7.

Pop-up artificial foliage system

Primary operative mode--blending

Secondary operative mode--screening, disguise

Threat avoidance capability--visible and near infrared

Pop-up artificial foliage can be used on building edges or in areas where vegetation has been stripped due to construction. If the properties of the lightweight camouflage screening system with radar scattering and radar transparency were incorporated into artificial pop-up foliage, this camouflage material would neutralize additional threats. The system was in an R&D phase as of December 1976. (145) B-84

b. Coloring materials

These materials are used to blend an object into its surroundings, distort prominent features, minimize the contrasts between the object and the background, and reduce shine.

1. Asphalt coatings

Primary operative mode--blending

Secondary operative mode--disguise

Threat avoidance capability--visual only

Asphalt coatings can be used to control erosion, reduce glare from highly reflective surfaces, and simulate roadways or vehicle tracks. They are stock items from DODISS. (145) B-30

guidance ATTACK THREATS/2 Camouflage**2. Dope, cellulose acetate butyrate, pigmented, camouflage**

Primary operative mode--blending

Secondary operative mode--disguise

Threat avoidance capability--ultraviolet, visible, near infrared

This material is used as the topcoat on fabric surfaces to obtain a camouflage finish. It is a stock item from DODISS. (145) B-37

3. Enamel, alkyd, camouflage

Primary operative mode--blending

Secondary operative mode--disguise

Threat avoidance capability--ultraviolet, visible, near infrared

This material is used primarily for spray applications on metal parts and surfaces as a camouflage color finish over zinc chromate primer. It is a stock item from DODISS. (145)

4. Lacquer, camouflage

Primary operative mode--blending

Secondary operative mode--disguise

Threat avoidance capability--ultraviolet, visible, near infrared

This lacquer is used on metal surfaces as a camouflage color finish and has ultraviolet, visible and near infrared reflective properties similar to background scenes. Best results are obtained when the material is applied over a zinc chromatic primer on pretreatment coating. It is a stock item from DODISS. (145) B-40

5. Camouflage by controllable color change

Primary operative mode--blending

Secondary operative mode--disguise

Threat avoidance capability--visible, near infrared

This is a practical camouflage system whose colors and color patterns can be continuously, controllably, and reversably varied on command using a liquid crystal approach. The system is in the R&D stage. (145) B-92

guidance ATTACK THREATS/2 Camouflage**6. Infrared and thermal coatings**

Primary operative mode--blending

Secondary operative mode--disguise

Threat avoidance capability--visible, near infrared, intermediate infrared, far infrared

These coating systems were developed with high visible and near infrared reflectance characteristics. They are durable, thermally stable to 350°F, and cured to room temperature. Colors can be specified. These coatings are in the R&D stage. (145) B-97

7. Color, camouflage

Primary operative mode--blending

Secondary operative mode--disguise

Threat avoidance capability--ultraviolet, visible, near infrared. (145) B-36

C. Exterior "tone down" painting

All controlled facilities on or near the site that are likely to reflect an appreciable amount of light are to be painted a tone-down color. Color selection must be in accordance with theatre tone-down color schemes. Facilities to be considered for painting shall include, but are not limited to, the following: communications tower and installed devices, buildings (including light-colored roofs), revetment, fences (excluding fabric), paved areas, and utility structures. Tone-down colors should complement nearby local national facilities, public and private. When installing new fences, consider using vinyl-coated fabric in tone-down colors. If vinyl-coated fabric is used, the coating must not be counted in measuring the fence fabric gage. Antenna dish covers and shrouds are to be pre-colored a tonedown shade. Painting with other than an approved paint is prohibited, as the paint could attenuate radio reception. (27) 1-10

Site buildings and bunkers must be camouflaged, with the color selection dependent on the surrounding environment. Once the scheme is decided, Federal Standard 595 should be consulted for the correct selection of colors. To achieve a two-dimensional camouflaged effect, prepare and apply one coat of primer and one finish coat of exterior acrylic emulsion paint in irregular patterns. Painting, sandbagging, and planting of trees and shrubs can constitute a comprehensive facility plan. Sandbags around the perimeter may have some usefulness for camouflaging; they are recommended for added protection.

guidance ATTACK THREATS/2 Camouflage

TT-P-19c paint shall be used for camouflaging the bunkers. This acrylic emulsion paint is intended for exterior concrete, stucco, and masonry surfaces which have been properly prepared. White paint is not suitable for use as a tint base. When colored paint is required, tints and medium-color paint should be specified. The material is not toxic under normal conditions. The paint should be set-to-touch in 15 minutes and dry through within 1 hour. If the paint is to be stored, it should be stable for at least 1 hour. See the full specification for freeze-thaw stability, heat stability, recoating, accelerated weathering, and fungus resistance. (98) 39

The shape and, to a limited degree, the shadow of buildings can be disguised by pattern painting the walls, roof, and surrounding ground. Large irregular patterns of two or three colors simulating the local terrain pattern can be applied so as to break the straight edges. (99) 69

Because of roof reflects more light than any other part of the building, the pattern should be darker and textured; when applicable, ground material should be used. Another way to reduce the shadow is to dig the building into the ground so as to reduce its height. (99) 70

The ground is also an important part of a comprehensive scheme. It can be sprayed with black bituminous emulsion to break the shadow; coarse textured materials such as cinders, slag, or coal washer refuse can be spread matlike around a structure in an irregular pattern to obscure the shadow; or, if practical, thick shrubbery or trees can be planted close to the sides of a building. (99) 70

Screening can also be used, especially to conceal access trenches from aerial or ground observation and fire. The netting can be garnished with local or synthetic material but should be applied in irregular bunches and blended where it comes in contact with the ground. (99) 70

Four basic colors are used, with the predominant color depending on that of the surroundings. These colors are: earth yellow, light green, dark green, and forest green. The following examples show how a building's context influences the choice of predominant color.

1. Located near earth roads with little adjacent vegetation--predominant color, earth yellow
2. Thick vegetation surrounds the building--predominant color, forest green
3. Located adjacent to or along rice paddies or similar cultivated areas--predominant color, light green
4. Buildings surrounded by low bushes--predominant color, dark green

guidance ATTACK THREATS/2 Camouflage

5. Buildings near a road with greenery and shrubs on three sides--predominant colors, earth yellow and forest green

6. Buildings surrounded by greenery--predominant color, light green

d. Decoys

Decoys are used for many purposes, but fixed installations usually use them to cause the enemy to think a specific course of action has been undertaken; to absorb some of the attack and thus reduce losses; to lead the enemy to believe that the primary mission of a fixed installation is something other than it actually is; to introduce one more element of uncertainty into the enemy's deliberations; to deceive the enemy as to the size of the installation; and to confuse impending attackers.

1. Building boards and prefabricated buildings

Primary operative mode--decoy

Secondary operative mode--disguise

Threat avoidance capability--ultraviolet, visible, near infrared, radar

Building boards include--

Hard pressed, vegetable fiber hardboard

Hard pressed, vegetable fiber wood particle board

Flat and corrugated asbestos-cement

Laminated vegetable fiber, hard pressed board

Prefabricated buildings include--

Twenty-by-40-foot multiuse building

Twenty-by-48-foot arctic climate building

Forty-by-100-foot metal frame structure

Shop-type building

Barracks-type building

Metal hangar

Sixteen-by-twenty-five-foot steel arch

One hundred-sixty-by-110-foot rigid frame hangar

Fifty-eight-by-80-foot trussless aircraft shelter

guidance ATTACK THREATS/2 Camouflage

Warehouse

Sectional general-purpose building

Two-story metal building section

Modular relocatable building

Classroom

Rigid aluminum frame

Sixty-by-80-foot steel frame

Metal round arch roof

2. Low-density urethanes

Primary operative mode--decoy

Secondary operative mode--blending and disguise

Threat avoidance capability--ultraviolet, visible, near infrared, intermediate infrared, far infrared

Depending on the bonding characteristics of the urethanes, the sharp delineating edges of buildings can be reduced and easily formed decoys can be constructed. Additional development of the reflectance properties of the urethanes could neutralize additional threats and surveillance systems.

Low-density urethanes are in the R&D stage. (145) B-104

e. Natural materials

Effective use of natural materials depends greatly upon proper site location of the elements of an installation. Natural cover means any feature of the land that can be exploited as camouflage--not only the natural cover provided by forest areas, but also shadows cast in natural depressions on the ground, the shade of buildings and trees, spotting of boulders and large shrubs on the ground, and contours of the natural terrain. Natural cover also includes cut vegetation and placement of spoil or debris. (145) 15

1. Hydroplanting of vegetation

Primary operative mode--blending

Threat avoidance capability--ultraviolet, visible, near infrared

This technique is aimed at the rapid growth of natural native vegetation in disturbed areas. Such vegetation is one of the best camouflage techniques because once established, maintenance requirements are low. Hydroplanting is in the R&D stage. (145) B-77

guidance ATTACK THREATS/3 Obscurants

3. Selection of obscurant materials for various DCS site conditions

Smoke and aerosol screening in fixed installation camouflage are not primarily to neutralize specific surveillance devices. Rather, this form of concealment is generally used during low-level attack conditions so that an enemy pilot and his guided munition devices are temporarily blinded.

a. Smoke bomb

Primary operative mode--screening

Secondary operative mode--Gamma-ray, ultraviolet, visible, near infrared

Smoke bombs effectively conceal elements for a short period of time. (145) B-66

b. Generator, smoke, mechanical and pulse jet

Primary operative mode--none

Secondary operative mode--none

Threat avoidance capability--none

The generator produces a smoke screen. (145) B-78

c. Grenade, hand, smoke

Primary operative mode--screening

Secondary operative mode--decoy

Threat avoidance capability--visible, near infrared

Small localized colored smoke screens can be created with this grenade. Also if used in a number of locations within a fixed installation, these smoke grenades can be effective decoys during an attack. (145) B-69

d. Smoke pots

Primary operative mode--screening

Secondary operative mode--visible, near infrared

Threat avoidance capability--visible, near infrared

Smoke pots can be used to produce smoke screens on land or water. They can be fired mechanically or electrically. (145) B70-72

guidance ATTACK THREATS/4 Antennas and Towers**4. a. Protective measures available for various DCS site conditions****1. Antennas and reflectors**

The smallest size antennas and towers (consistent with reliable operation) should be used to provide a reduced target.

There seems to be no simple way to harden tower-mounted antennas and reflectors. However, it seems unnecessary to harden the microwave reflectors because they can withstand damage from small-caliber-weapon fire without a major loss of signal output. The type of microwave antenna most vulnerable to such damage is the pressurized cornucopia. However, even this antenna can continue to operate without requiring immediate repair. The cornucopia cover can be painted black to diminish its usefulness as a target. (63) 86 Cover antennas with radomes when possible to limit feedhorn visibility and access. Install microwave antenna shrouds to obscure the target. (27) 1-25

A pressurized antenna combines the feedhorn and reflector in one unit resembling a large cornucopia. The waveguide is kept under slight pressure to prevent corrosion through the entry of moist, ambient air. The entire antenna is kept pressurized by the plastic cover, which maintains the seal. Some hunters in Alaska apparently have found that this big white cover is an excellent target for sighting their rifles. Although the resulting holes do not affect station operation immediately, the loss of pressure can eventually lead to corrosion and degraded performance. To repair the damage, someone must climb the tower and patch the holes. Therefore, a pressurized antenna is considered susceptible. (63) 42

2. Towers

Ground-mounted antennas can be included in tower hardening measures because they are mounted near the base of the tower. A reinforced concrete sleeve can be used to enclose the antenna support structure for hardening. (63) 87

To harden the base of a self-supporting or guyed microwave tower, each main tower support can be encased in a reinforced concrete sleeve extending about 20 feet (6 meters) above ground. Or 9-gage (3.77- millimeter) steel wire chainlink fencing or corrugated metal can be installed over the top of a tower revetment at a minimum 45-degree plane. The edge must be detailed such that falling debris will not become caught on projections. A building that completely surrounds the tower base and provides a physical barrier to its access can be constructed from four prefabricated buildings. There may be enough space within the tower building for the shelters that house communications and power equipment. If so, the tower

guidance ATTACK THREATS/4 Antennas and Towers

building could also function as the equipment building. Furthermore, a waveguide bridge would not be required and overall construction requirements might decrease. The roof of the tower building can be designed strong enough to withstand extremes in weather, but not strong enough to support the weight of a person. The roof also can be heated to prevent snow accumulation. The roof is designed to force the intruder to go through the building, rather than climb over it to reach the tower. A knockout or irritant gas can be used inside the building, and an electrified fence can be installed around it, as was suggested for the equipment building. Depending on the site layout, the same fence can be used to enclose the equipment and the tower buildings. (63) 86

When new communications towers are to be installed, consideration shall be given to precast concrete towers. Such towers are becoming more economical than steel structures in some countries, and they offer excellent physical protection and obscurity to the waveguide. However, when specifying concrete towers, care must be taken to provide a reasonable allowance in the initial design for increased mission capacity (structural loading). This allowance is site-dependent and is estimated based on the likelihood of an expanded mission. (27) 1-25

3. Guy wires

Enclose all guy wires in metal pipe for at least 20 feet (6.1 meters) above ground level. Encase guy wire anchors in concrete bunkers. The design must allow for periodic maintenance inspection of the guy wires and anchors. (27) 1-21

For a guyed tower, each guy-wire anchor can be enclosed by a separate prefabricated shelter. Galvanized steel-pipe sleeves can protect the guy wires. The sleeves should extend to about 20 feet (6 meters) above ground. A single securely locked door should provide access to each shelter. A gas discharge can be activated when an intruder enters the shelter. (63) 87

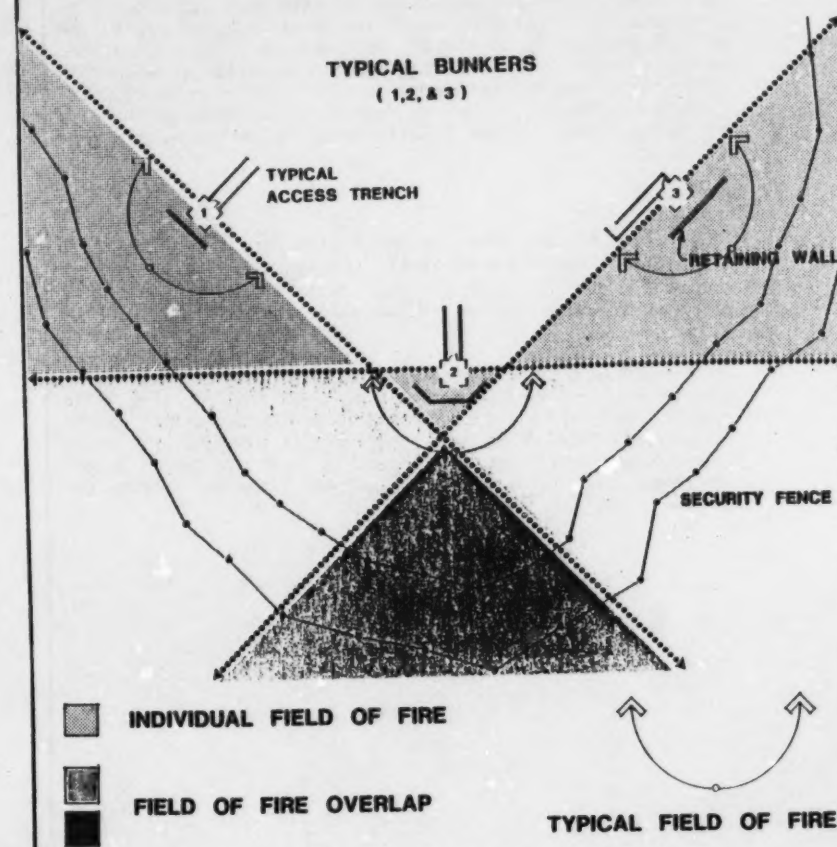
guidance ATTACK THREATS/5 Bunkers

5. a. Site location of bunkers

The purpose of the bunkers is to cover enemy avenues of approach, to have fields of fire, and to be mutually supportive. Siting is an important factor in bunker efficiency.

Bunkers for protection against air raids and artillery should be located to take advantage of natural cover. Bunkers for defense against ground attack should be located to cover avenues of approach and provide the best fields of fire.

When siting bunkers, some fields of fire will overlap, which is necessary for an efficient system.



guidance ATTACK THREATS/5 Bunkers

If a bunker is sited outside a fence, it should be located on a military crest covering a critical avenue of approach. From such a military crest the enemy can be engaged 100 to 200 meters to the front. Do not pull back to hide behind a fence and allow the enemy to approach within 20 feet of the facility's perimeter.

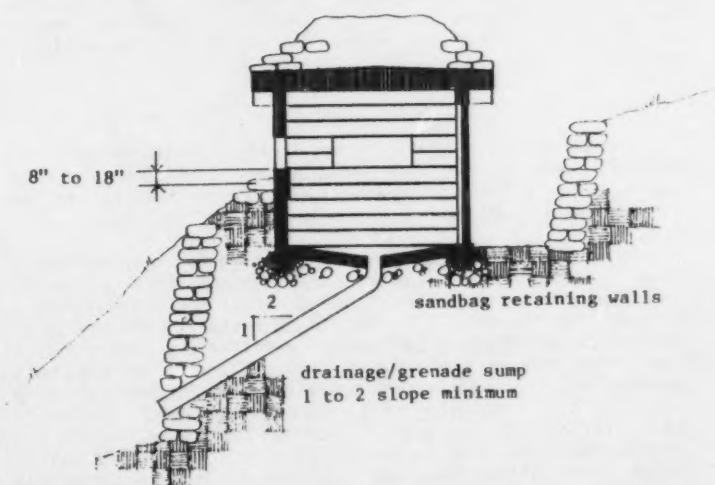
A fence is not a very good barrier against well-trained infantrymen; when penetrated, the facility's mission can be in danger.

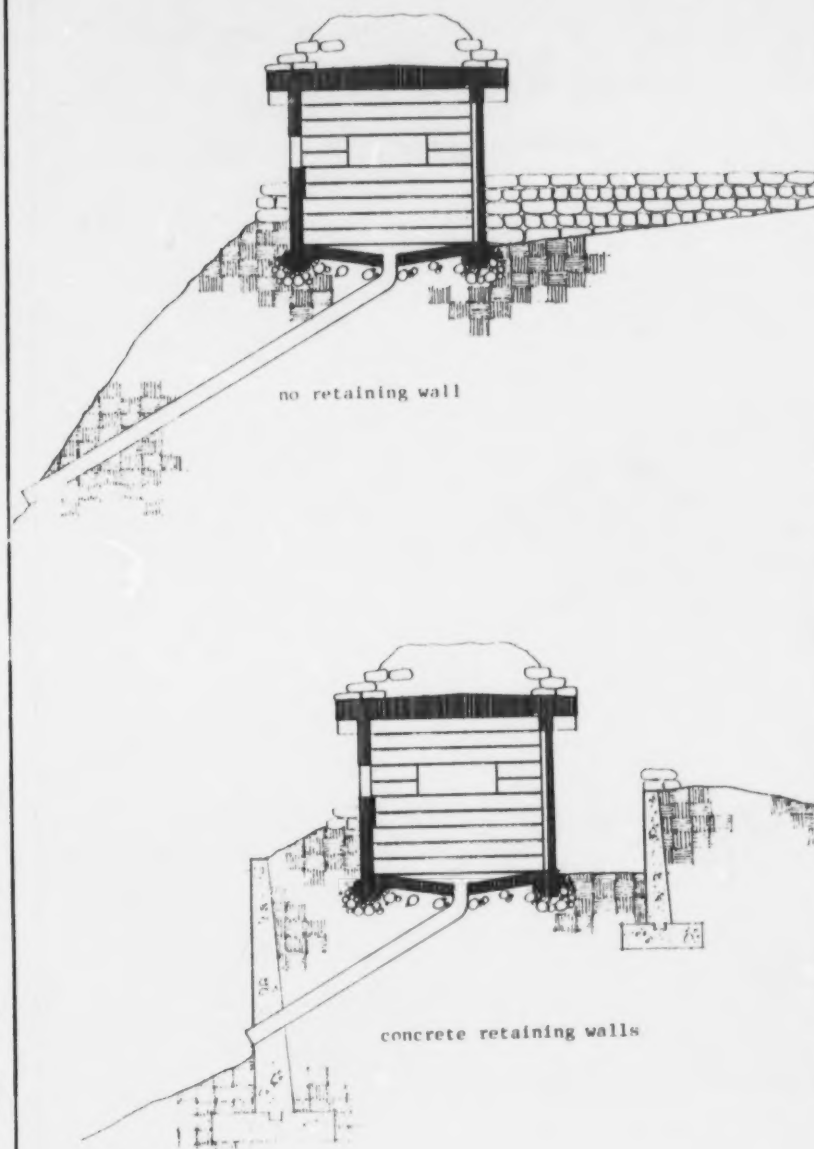
b. Bunker design configuration

1. Precast concrete log perimeter bunker

The bunkers are very adaptable to different sites due to their size and simple foundation. The one necessity is a slope toward the site perimeter for the drainage/grenade sump. The optimum excavation is for the grade to be 8 to 12 inches below the firing ports. If cut or fill is necessary in siting a bunker, retaining walls of reinforced concrete or sandbags can be used to accommodate a severe grade change.

Information concerning a "concrete log" design was found in the literature search, but the individual "logs" are so heavy they require equipment for assembly. Since precasting such "logs" is complicated and since the design requires a



guidance ATTACK THREATS/5 Bunkers**guidance ATTACK THREATS/5 Bunkers**

variety of different shaped logs for a single bunker, this design was thought to have no advantages over the concrete panel bunker. (185) 39

Except for very permanent-type installations for which construction equipment and skilled labor are available or for which very thick, hard protection is imperative, cast-in-place concrete security bunkers such as those found in the literature search appear too complicated for any significant application. Problems of forming and pouring make cast-in-place bunkers inefficient and uneconomical when compared with precast panel bunkers. (185) 40

2. Perimeter bunker with offset firing ports

This structure is constructed with a timber frame sheathed with 2 by 12s buried to the firing ports and covered with loose earth or sandbags. The unique feature of the bunker is its offset firing ports. The ports open on both sides at an angle of approximately 45 degrees to the front, thus preventing the attacking enemy from firing directly into the structure as they approach. Mutual support between adjacent structures to protect their front is imperative, as stated earlier under "Site Location of Bunkers." (146) 37 The structure can withstand an 82-millimeter HE contact burst on the overhead cover (loose dirt), a 50-caliber small arms attack, and fragmentation and blast effects from a 155-millimeter HE round at a distance of 5 feet.

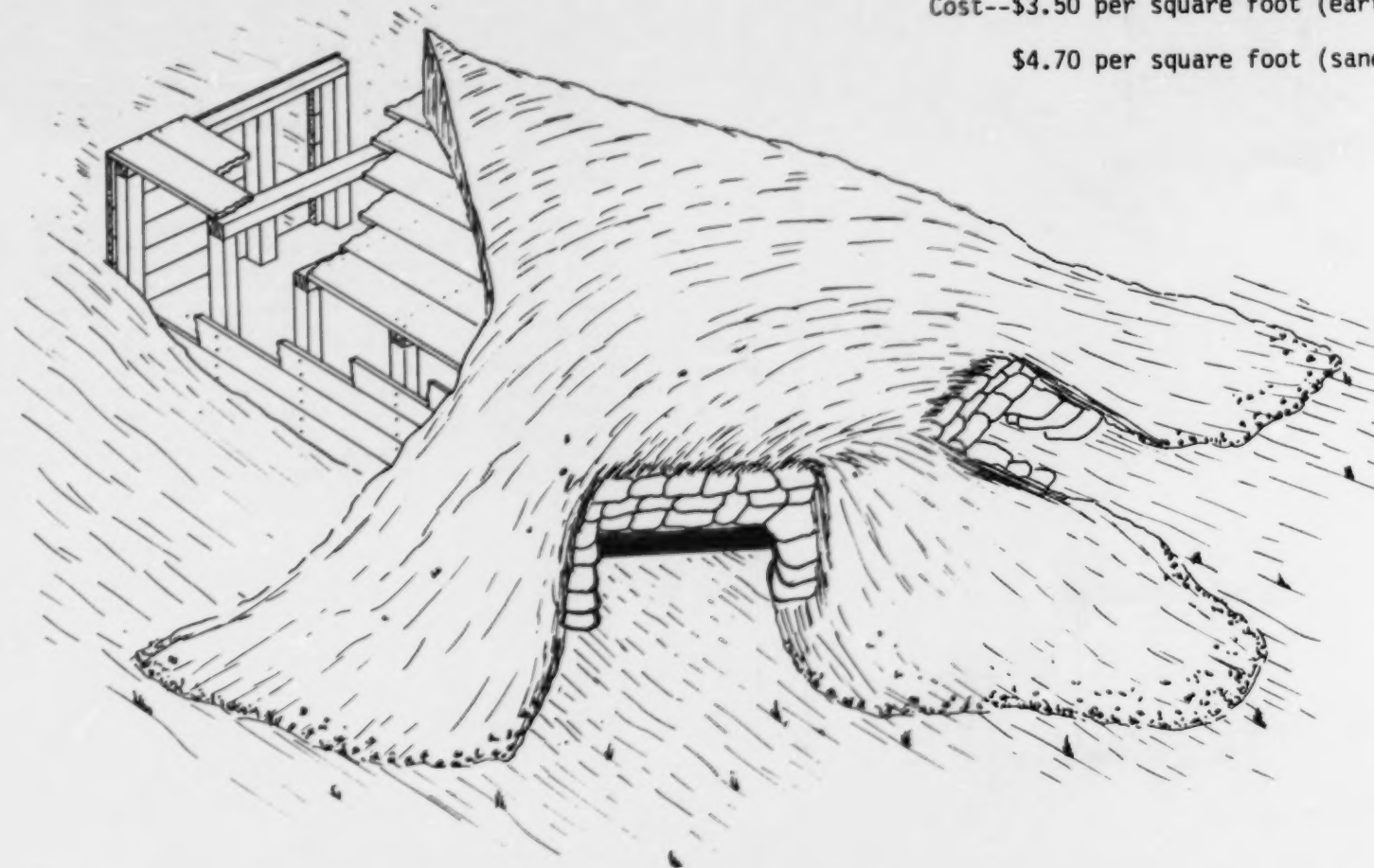
guidance ATTACK THREATS/5 Bunkers

Construction time--42 hours (earth cover)

100 hours (sand bags)

Cost--\$3.50 per square foot (earth)

\$4.70 per square foot (sand)



EARTH-COVERED PERIMETER BUNKER WITH OFFSET FIRING PORTS.

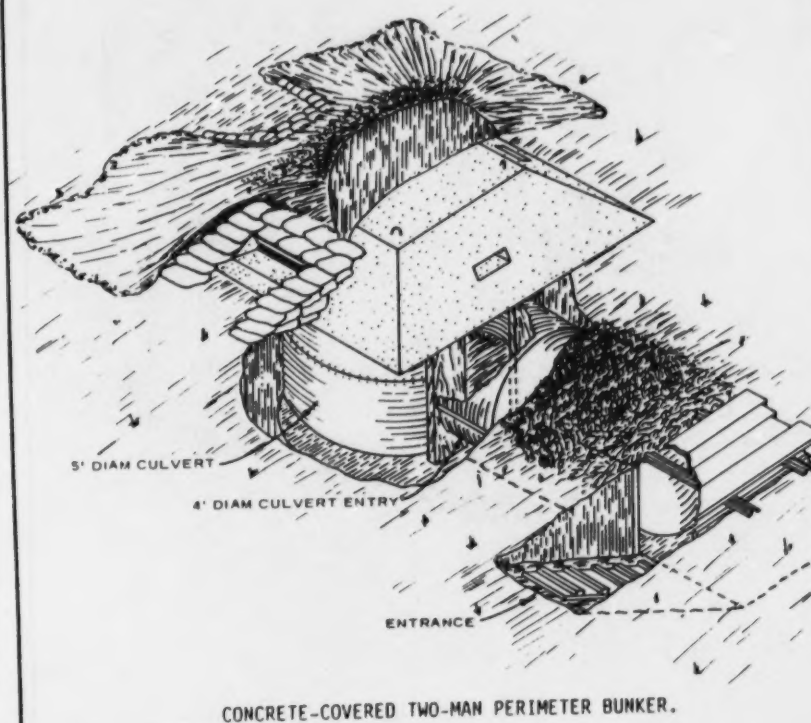
guidance ATTACK THREATS/5 Bunkers

3. Concrete-covered two-man perimeter bunker

This bunker consists of a prefabricated steel-reinforced concrete shell positioned over a two-man corrugated-metal-pipe reinforced excavation. Each of the four sides has firing ports or peep holes. The bunker is entered through a crawlway at the rear. Once in place, the structure is covered with sandbags or loose earth. The concrete shell is 6 inches thick and should be provided with lifting lugs for transport. (146) 38 the structure will withstand a 107-millimeter HE contact burst on the overhead cover, a 50-caliber small arms attack, and fragmentation and blast effects of a 155-millimeter HE round detonated 5 feet away. The system offers good protection and can be mass provided, although engineer support may be required. (146) 100

Construction time--78 hours

Cost--\$6.30 per square foot



guidance ATTACK THREATS/5 Bunkers

4. Rectangular timber-frame perimeter bunker

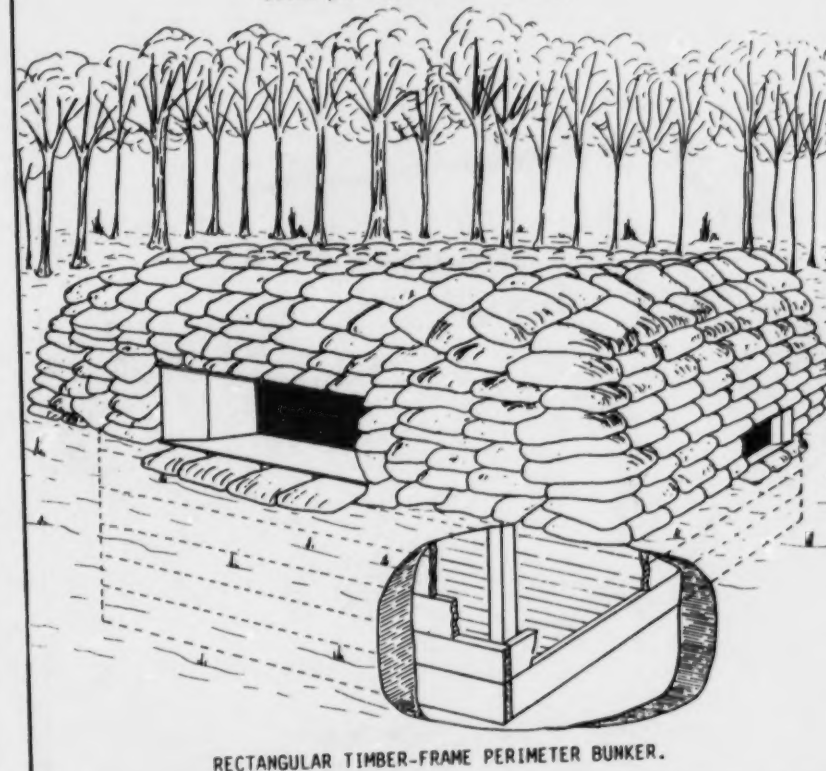
This design consists of a rectangular timber frame sheathed with 2 by 12s roofed with a solid deck of 4 by 4s and covered with either sandbags or loose earth. Fire ports are located in the front and on the sides; the entrance is at the rear. To maximize protection, the structure should be buried to the bottom edge of the firing ports. (146) 38 A 107-millimeter HE burst on the overhead cover can be resisted, as can small-arms fire (7.62 millimeter) and 155-millimeter HE bursts at 5 feet. The system can be preassembled or panelized. (146) 100

Construction time--89 hours (sandbags)

37 hours (earth)

Cost--\$4.70 per square foot (sandbags)

\$3.50 per square foot (earth)

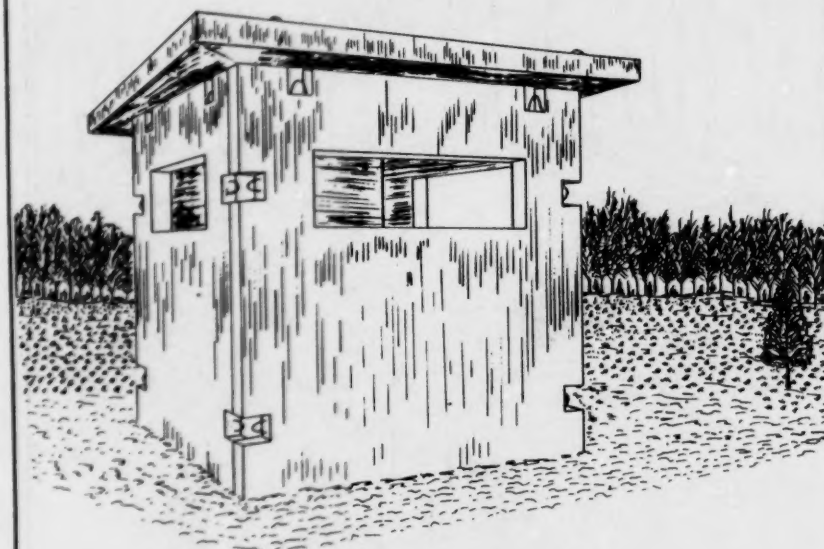


guidance ATTACK THREATS/5 Bunkers**5. Precast concrete panel perimeter bunker**

This design can be prefabricated in a rear area and shipped to the site. It was used widely in Vietnam. Large firing ports provide maximum visibility. Although usually used where above-ground construction is needed, this bunker can easily be placed partly underground (up to the firing ports). (146) 39 If sandbag cover is used, the structure can defeat a 107-millimeter HE contact burst on the cover, along with 50-caliber small arms and fragmentation and blast effects from a 155-millimeter round at 5 feet. (146) 100

Construction time--102 hours

Cost--\$4.90 per square foot



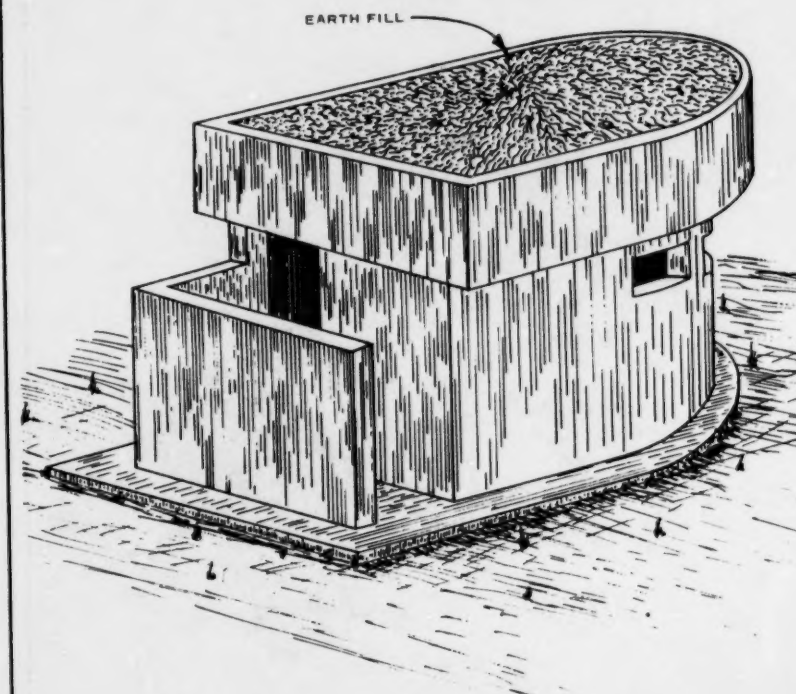
PRECAST CONCRETE PANEL PERIMETER BUNKER

guidance ATTACK THREATS/5 Bunkers**6. Cast-in-place concrete bunker**

These bunkers are practical only in areas where skilled labor and the necessary construction equipment are available or if very thick, hard protection is imperative. Protection is comparable to that provided by the precast concrete panel perimeter bunker. (146) 40

Construction time--300 hours (estimated)

Cost--\$12.10 per square foot



CAST-IN-PLACE CONCRETE PERIMETER BUNKER

guidance ATTACK THREATS/5 Bunkers**7. Rating the bunkers**

A team of Army evaluators was requested from Fort Benning, GA. The team consisted of a captain, a lieutenant, and a sergeant first class from the Corps of Engineers; two captains from field artillery; and two captains and one lieutenant from the Infantry. The team was guided through the test site before the test. Afterwards, they were asked to re-examine the structures and fill out a worksheet (drawing from their own experiences only). Ratings are as follows. "Best I have seen" = 5 points; "As good as any other I have seen" = 4 points; "Average" = 3 points; "Below average" = 2 points; and "Unsatisfied" = 1 point.

a. Perimeter bunker with offset firing ports

This bunker design concept was found in the files of various Army units and was mentioned during interviews with Army personnel. The most complete design plans were taken from the files of the 159th Engineers Group. Rating of 3.8

b. Concrete-covered two-man perimeter bunker

This bunker design was found in the files of the 4th Engineer Battalion. Rating of 4.4

c. Rectangular timber-frame perimeter bunker

This bunker design was found in the files of the 18th Engineer Brigade. The 101st Aberdeen Division prefabricated similarly designed bunkers of heavier timbers and transported them by helicopter from rear areas. Rating of 3.4

d. Precast concrete panel bunker

This design was taken from the files of the 92nd Engineer Brigade but is found in many other files. Apparently it was used widely in Vietnam. Rating of 4.12.

e. Cast-in-place

Not rated.

C. Bunker size and construction materials**1. Precast concrete log perimeter bunker**

The bunker floor is a 4-inch-thick poured concrete slab with 6 by 6 #8 WWF reinforcing. It should slope 12 percent to the center (approximately 6 inches) and have an 8-inch

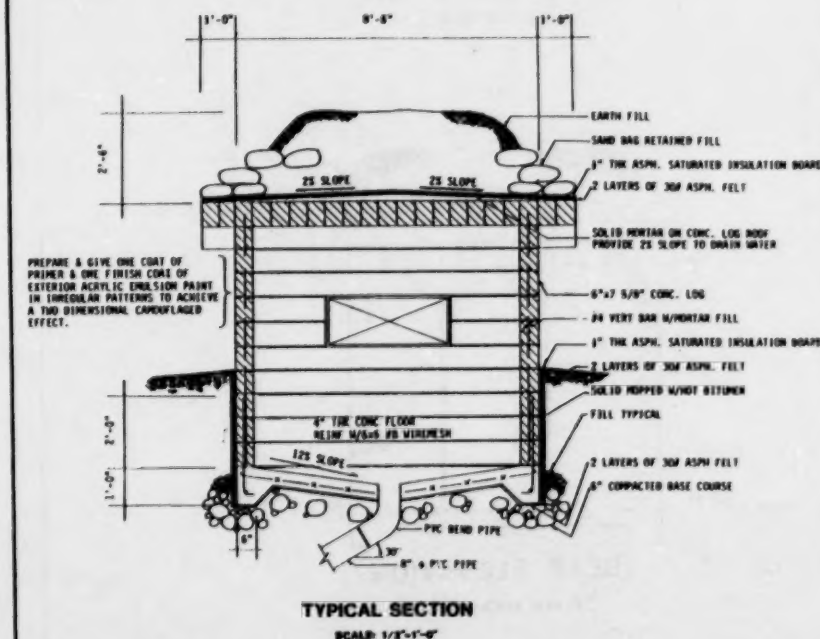
guidance ATTACK THREATS/5 Bunkers

polyvinyl chloride combination drainage/grenade sump. This sump exits downgrade of the bunker, depending on site conditions or modifications. Examples are shown further in "Guidance."

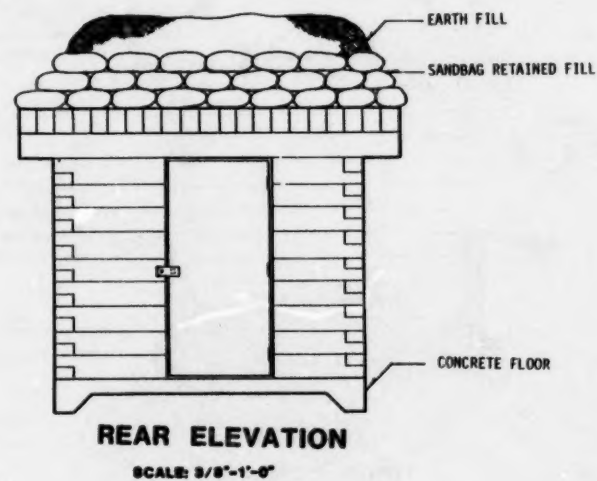
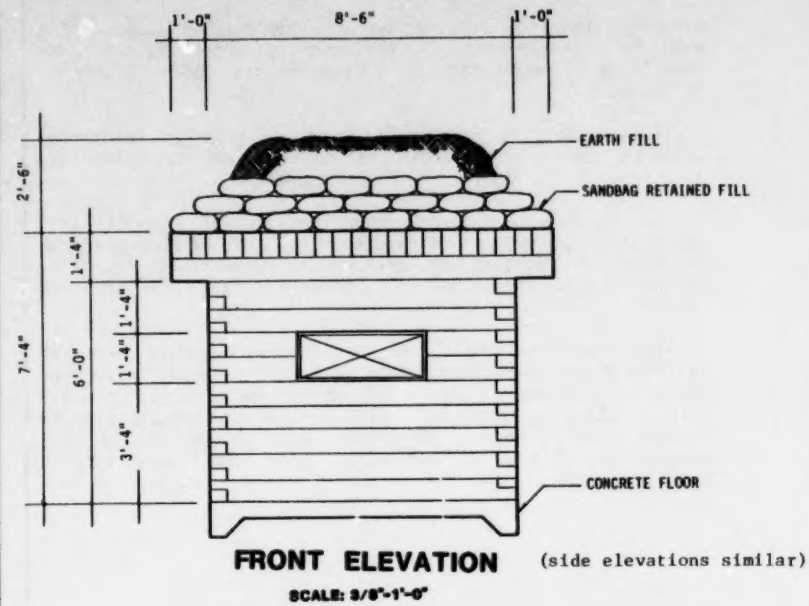
This bunker is made of stacked, interlocked reinforced concrete logs. The logs are modular and made in five different types. (See "Building Components.")

The bunkers meet requirements for storage of small arms ammunition, grenades, and pyrotechnics. In wartime they can be used as fighting or protective bunkers—for example, against ground attack or air/artillery attack, depending on location.

The recommendation is 8 feet 6 inches square, with an interior floor-to-ceiling height of 6 feet 8 inches. The roof has a solid mortar crown on top of the log modules, with a 2 percent slope to help drain water. The roof should also be waterproofed as shown. The earth fill on top should be a minimum of 2 feet 6 inches, with a continuous sandbag retaining wall.



guidance ATTACK THREATS/5 Bunkers

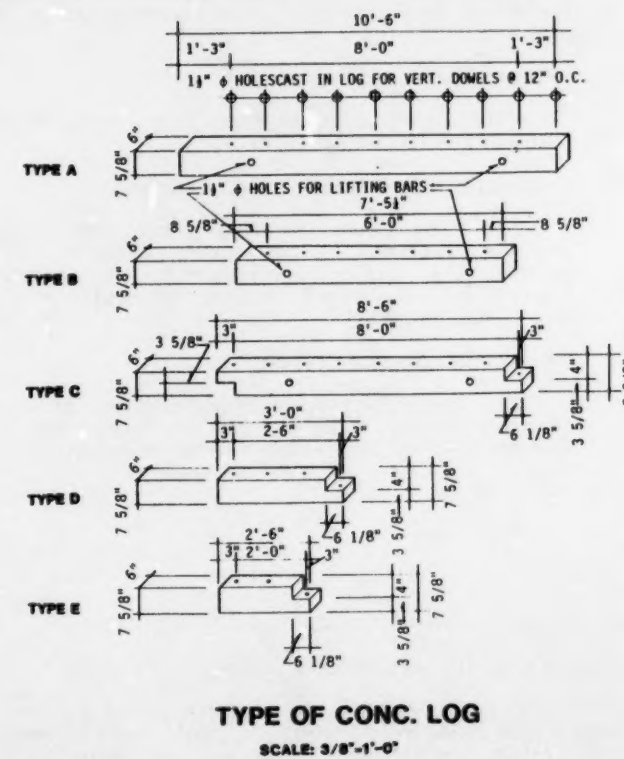


guidance ATTACK THREATS/5 Bunkers

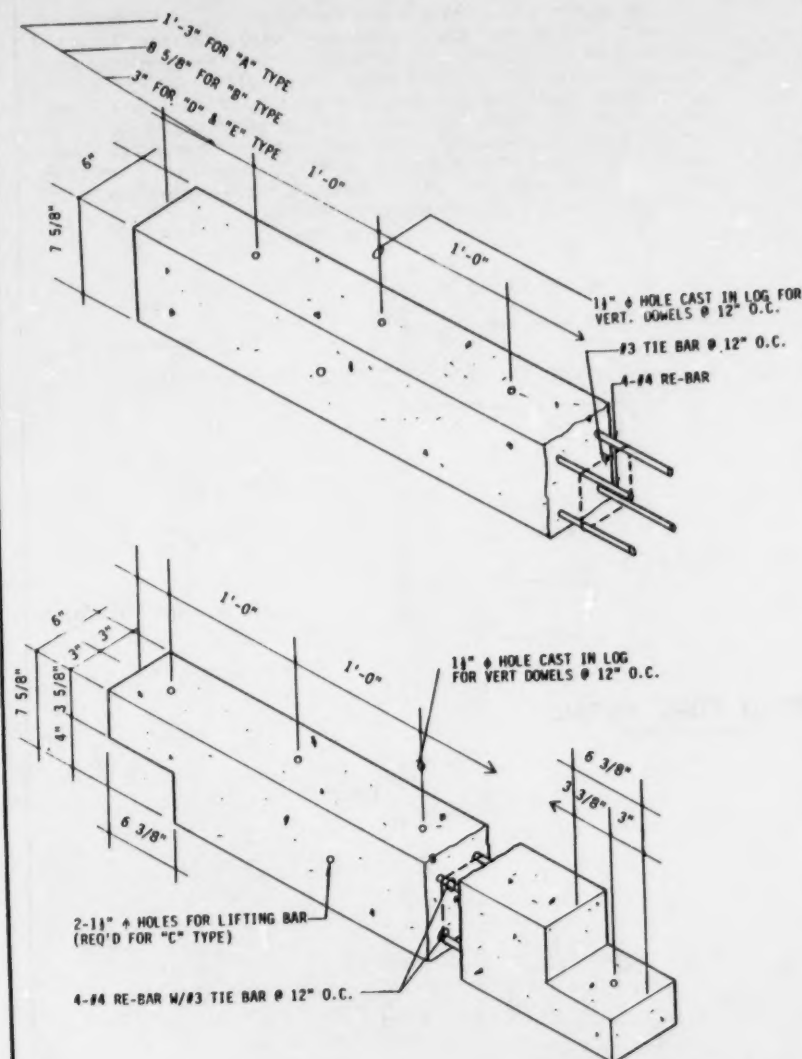
Construction materials

1. Precast concrete log perimeter bunkers

Logs--The concrete logs are precast into five different types (see below). They are slid down the #4 reinforcing bars, which are already set into the foundation slab at 12 inches on-center. Since the logs overlap, opposite sides of the bunker have to be completed before laying adjoining walls. The mortar fill between each log is 3/8-inch thick.



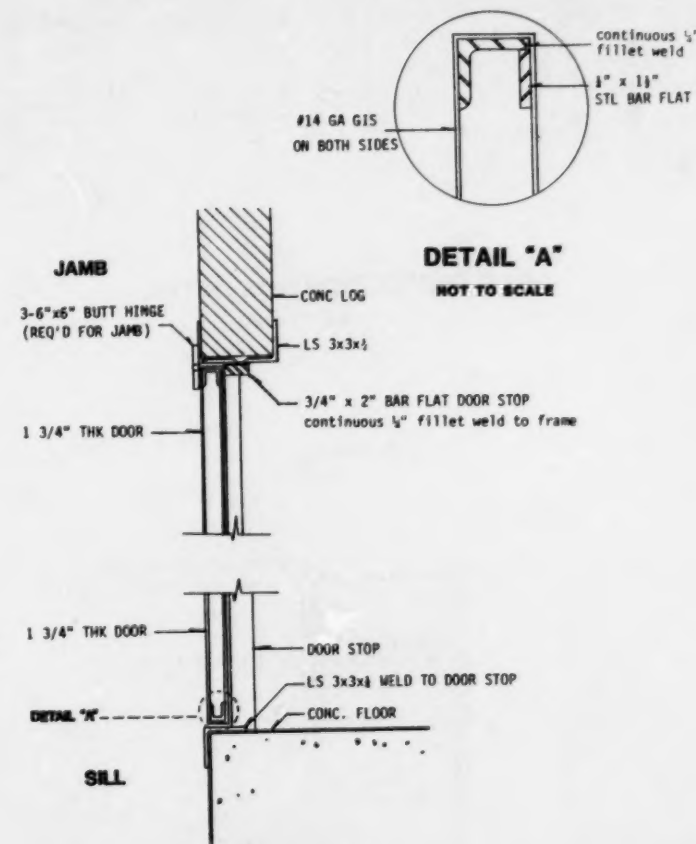
guidance ATTACK THREATS/5 Bunkers



CONC. LOG DETAILS
SCALE: 1-1/2"-1'-0"

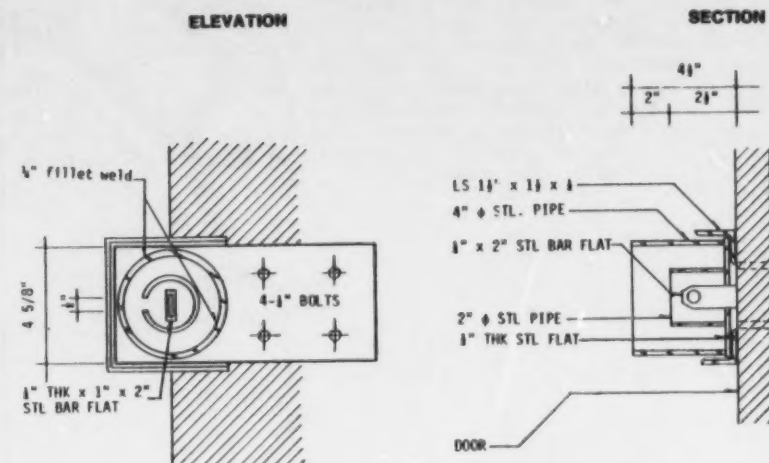
guidance **ATTACK THREATS/5 Bunkers**

The access door should be double-faced, 14-gage, galvanized iron steel plate with an anti-bolt cutting protective device for the lock. The door dimensions are 3 feet by 6 feet by 1 3/4 inches thick. Three 6-by-6-inch butt hinges with fixed pins should be welded to the door and its frame. A pull handle constructed from a #4 reinforcing bar should be installed on both sides of the door. The inside face of the door will also have two 6-inch-long heavy-duty latch bolts (see drawing).

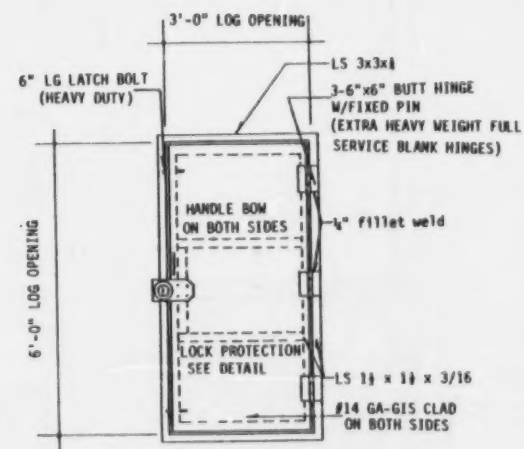


DOOR DETAIL
SCALE: 1-1/2"=1'-0"

guidance ATTACK THREATS/5 Bunkers



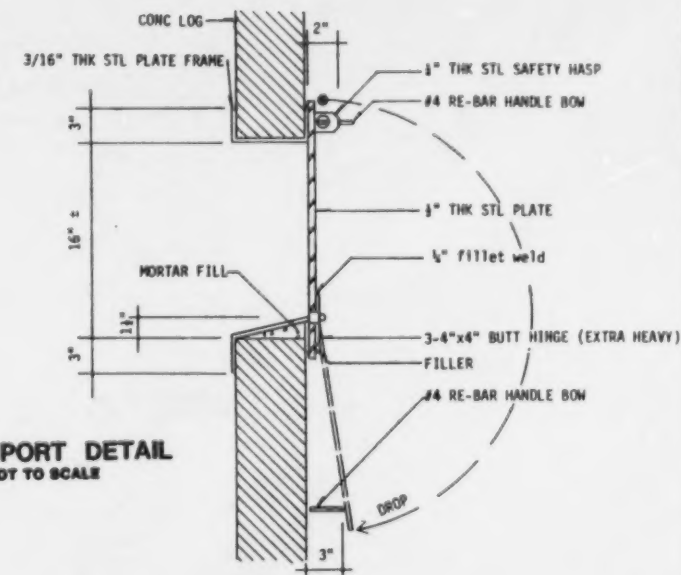
LOCK PROTECTION BOX DETAIL
NOT TO SCALE



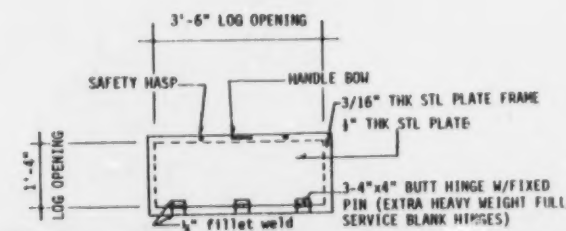
DOOR ELEVATION
SCALE: 1/2"-1'-0"

guidance ATTACK THREATS/5 Bunkers

The bunker should have three firing ports, 16-by-42-inches on each wall except the access door wall, located 3 feet 4 inches from the floor. The panel covering the opening should be constructed of 1/2-inch-thick steel plate against a 3/16 inch-thick steel plate frame. Three 4 by 4 inch butt hinges with fixed pins should be welded to the panel and frame at the bottom edge of the panel. The top center of the panel should have a pull handle constructed of #4 steel re-bar. The panel is locked through two safety hasps of 1/4-inch-thick steel located on both sides of the pull handle.



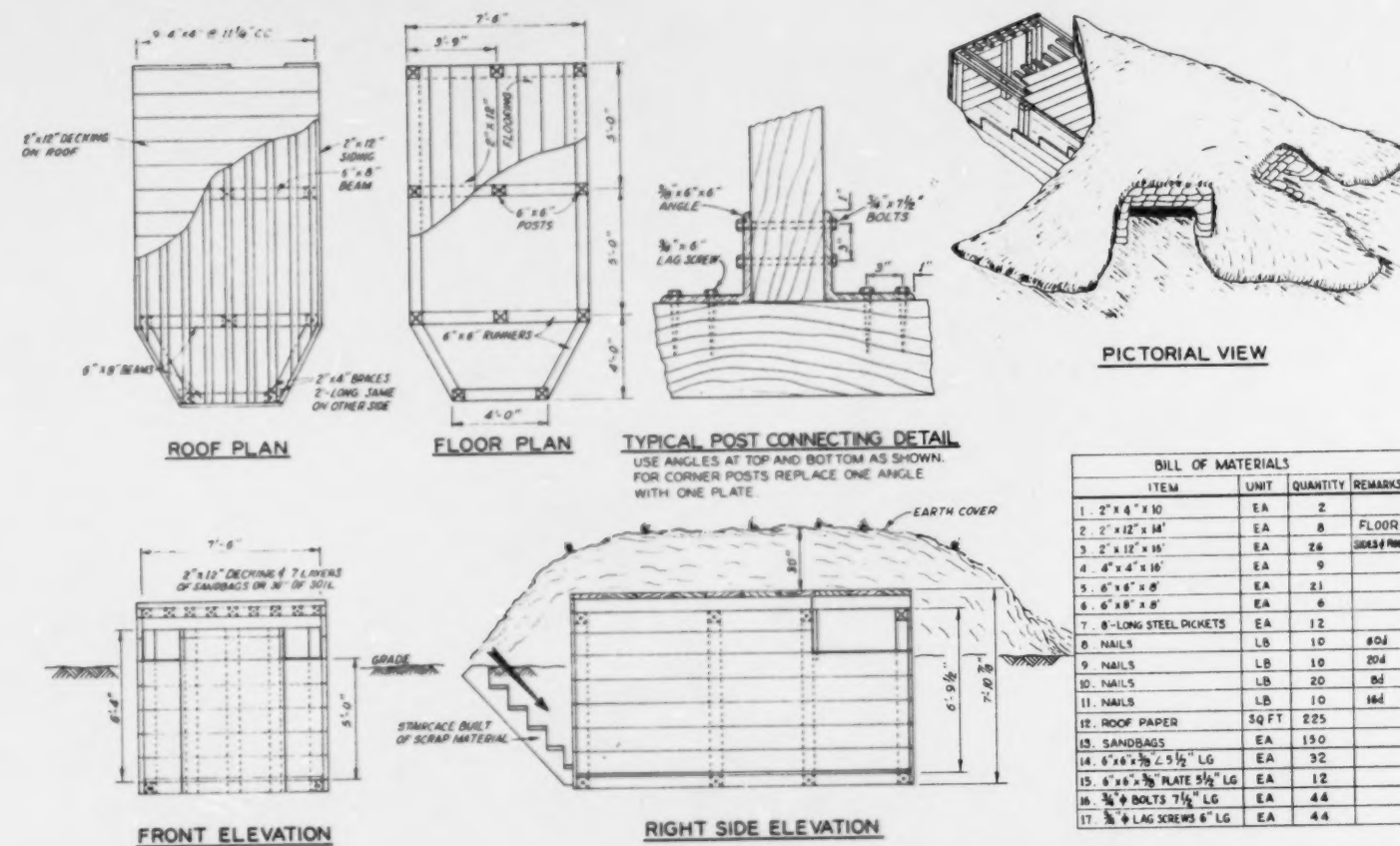
FIRING PORT DETAIL
NOT TO SCALE



FIRING PORT ELEVATION
SCALE: 1/2"-1'-0"

guidance ATTACK THREATS/5 Bunkers

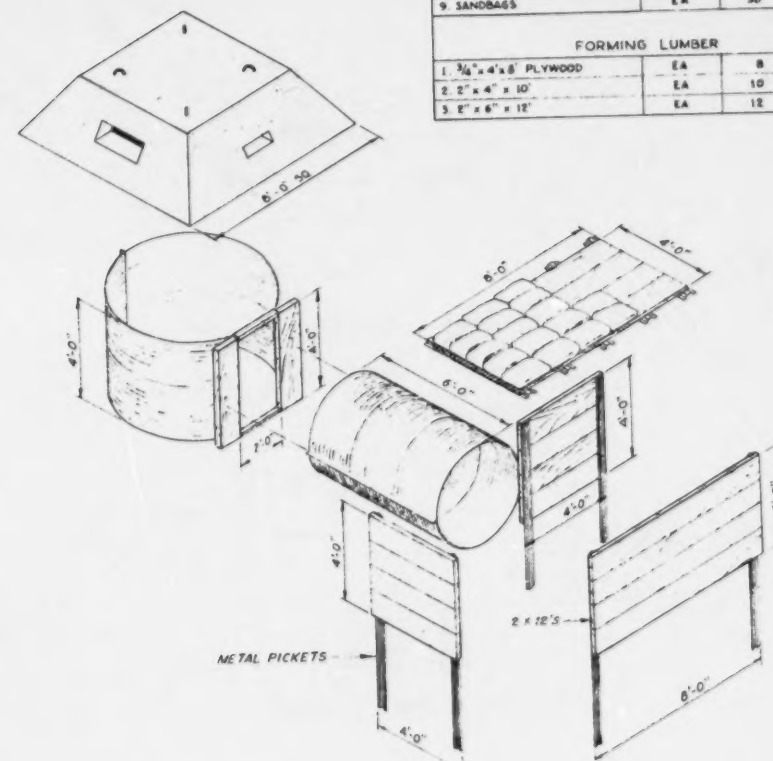
2. Perimeter bunker with offset firing ports



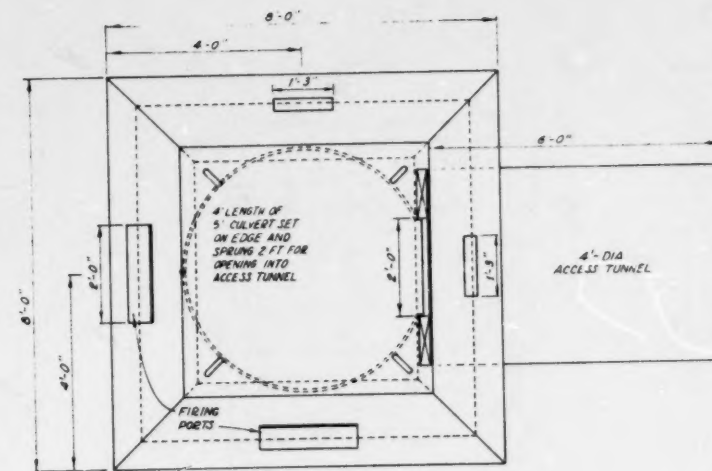
guidance **ATTACK THREATS/5 Bunkers**

3. Concrete-covered two-man perimeter bunker

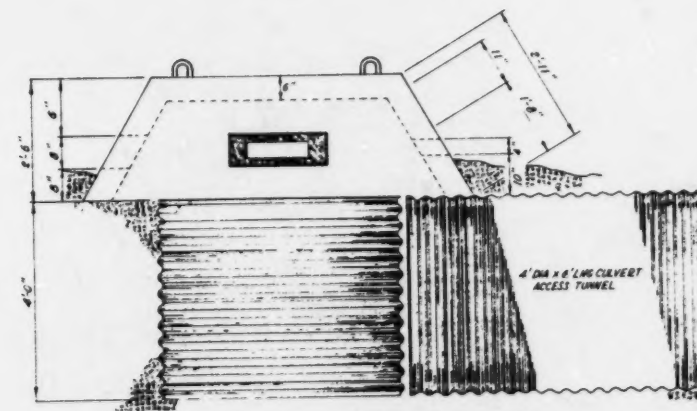
BILL OF MATERIALS			
ITEM	UNIT	QUANTITY	REMARKS
1. 2" x 4" x 8'	EA	4	FOR INTERIOR WALLS
2. 2" x 12" x 8'	EA	14	
3. 48" x CMP	LF	8	
4. 60" x CMP	LF	4	
5. 6" STEEL PICKETS	EA	12	
6. REBAR #4	20' LENGTHS	10	(240 LF)
7. REBAR #6	20' LENGTHS	18	(360 LF)
8. CONCRETE	CU YD	3	
9. SANDBAGS	EA	50	
FORMING LUMBER			
1. 3/4" x 4" x 8' PLYWOOD	EA	8	
2. 2" x 4" x 10'	EA	10	
3. 2" x 6" x 12'	EA	12	



guidance ATTACK THREATS/5 Bunkers

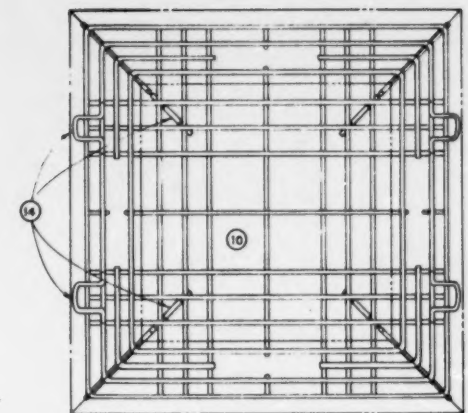


PLAN

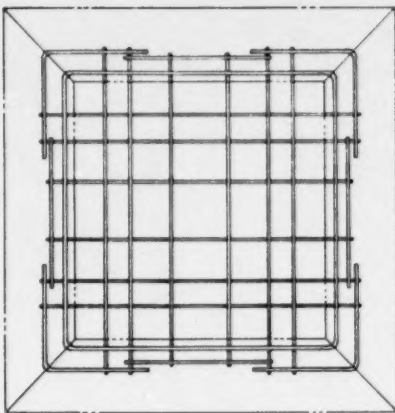


ELEVATION

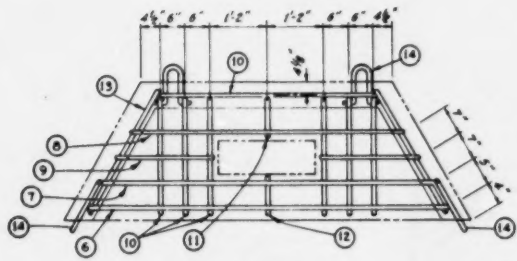
guidance ATTACK THREATS/5 Bunkers



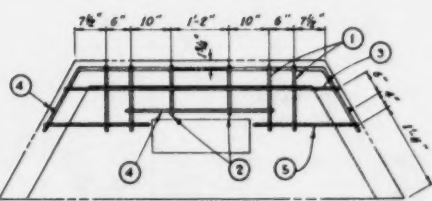
TOP VIEW
ALL #6 REBAR



TOP VIEW
ALL #4 REBAR

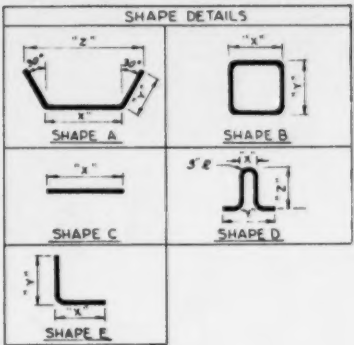


REBAR PLAN
ALL #6 REBAR



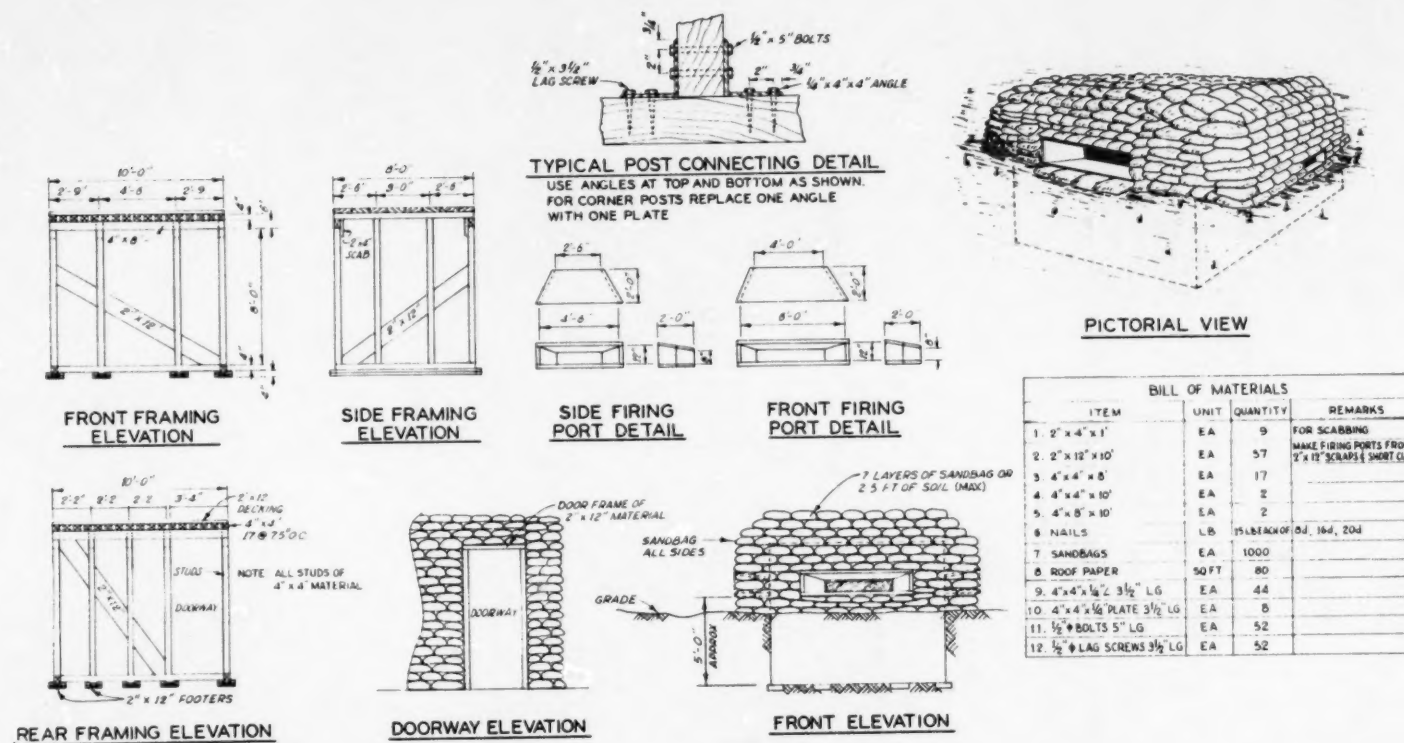
REBAR PLAN
ALL #4 REBAR

NOTE:
1. FABRICATE REBARS PER SCHEDULE
2. MAINTAIN 1" CLEARANCE BETWEEN
REBARS AND CONCRETE SURFACE.



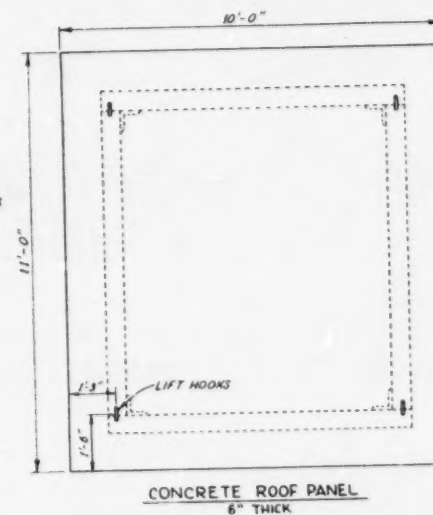
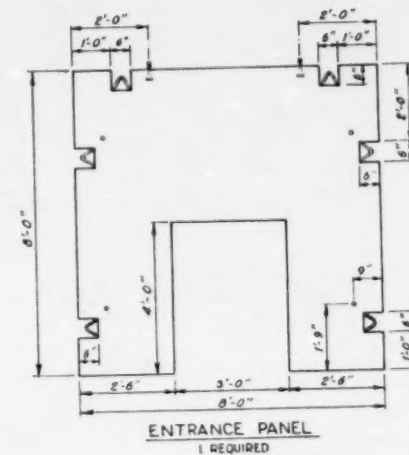
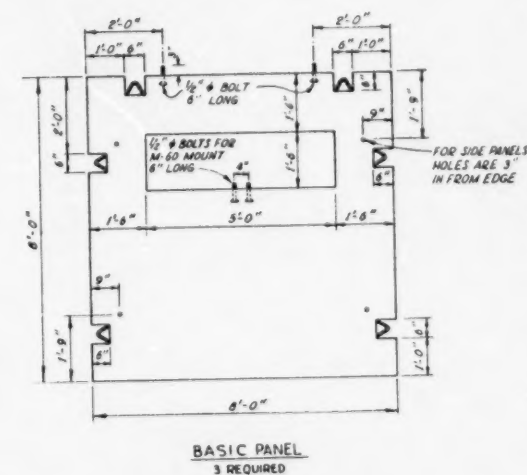
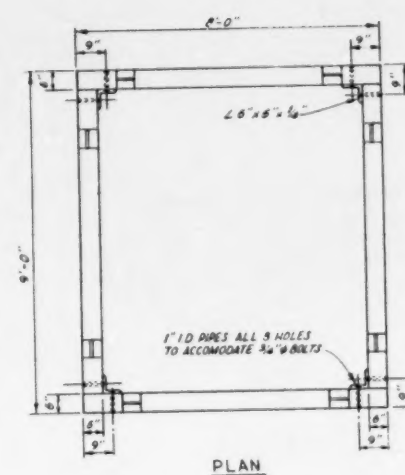
guidance ATTACK THREATS/5 Bunkers

4. Rectangular timber-frame perimeter bunker



guidance **ATTACK THREATS/5 Bunkers**

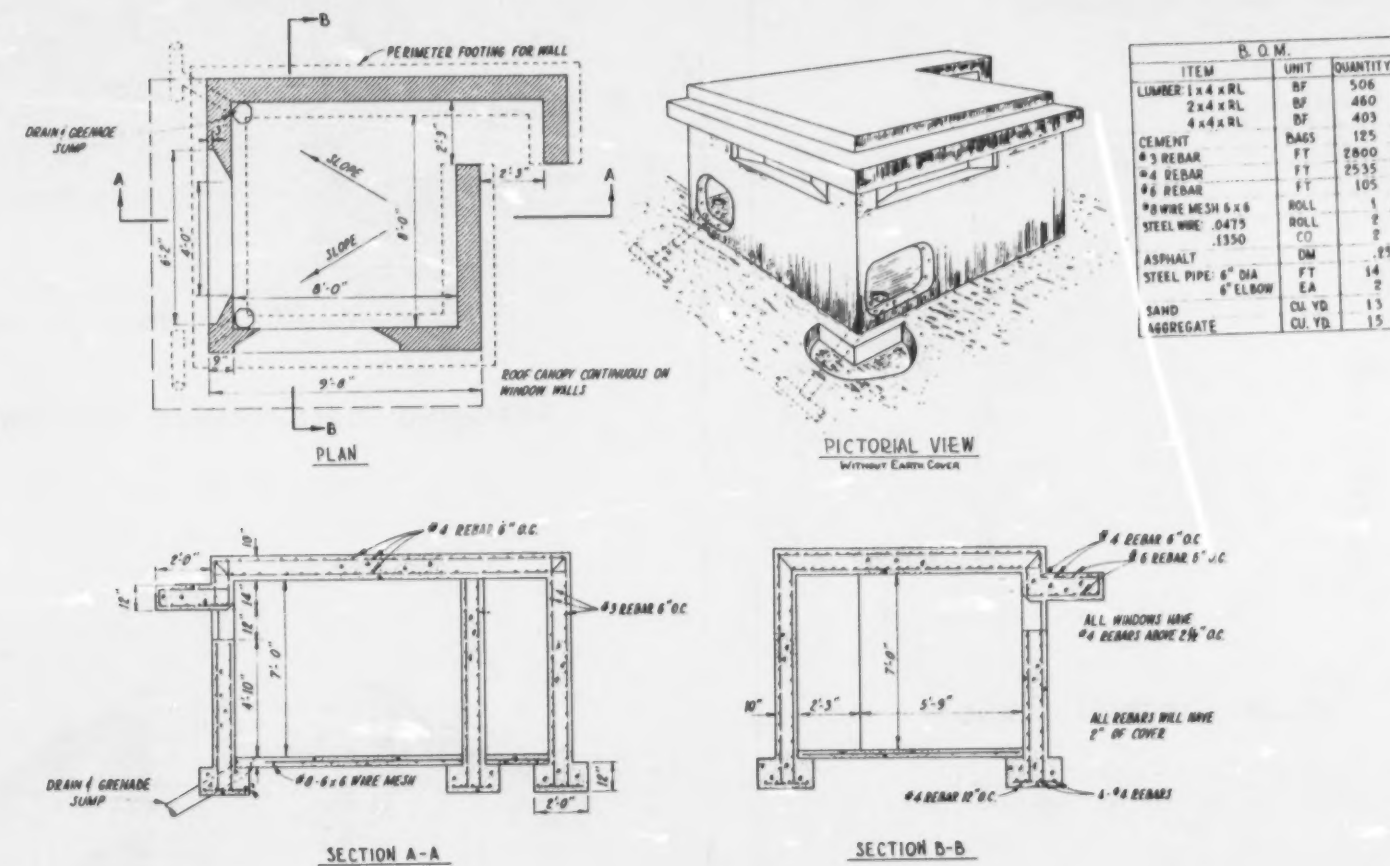
5. Precast concrete panel perimeter bunker



BILL OF MATERIALS			
ITEM	UNIT	QUANTITY	REMARKS
1 2" x 4" x 14'	EA	4	
2 CONCRETE	CU YD	7	
3 REBAR #4	20' PC	65	(1300 LF)
4 BOLTS/NUT 3/4" x 7"	EA	16	
5 BOLTS/NUT 1/2" x 6"	EA	10	
6 STEEL ANGLE 1/4" x 6" x 5"	EA	4	
7 7/8" x 6" PIPE	EA	16	

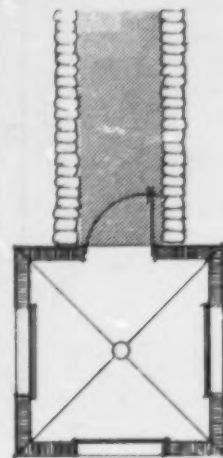
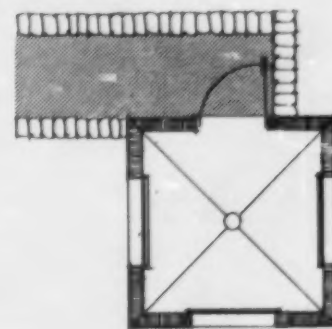
guidance ATTACK THREATS/5 Bunkers

6. Cast-in-place concrete perimeter bunker



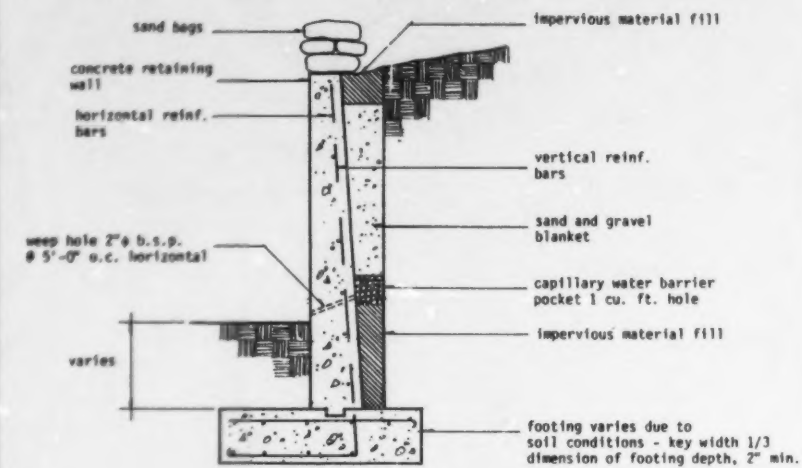
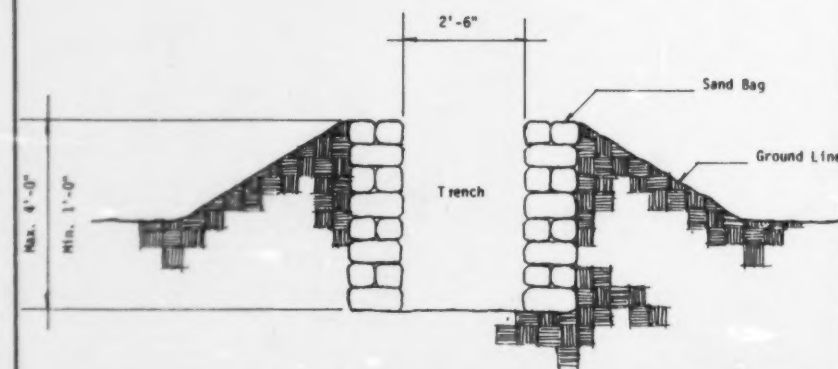
guidance ATTACK THREATS/5 Bunkers**Access via trenches**

The length, depth, and orientation of the bunker access trench depend on the particular site. The retaining walls for the trench can be either reinforced concrete or sandbags. If the walls are concrete it is recommended that sandbags be used above grade for additional protection. When the trench cut is deep and space is at a premium, a concrete wall can be a more efficient system since sandbags require a slope to the grade cut.

**A****B****ACCESS TRENCH PLANS**

A Recommended construction of access trench if bunker is sited on steep embankment.

B Recommended construction of access trench if bunker is sited on shallow embankment.

guidance ATTACK THREATS/5 Bunkers**RETAINING WALL TRENCH SECTION****SANDBAG TRENCH SECTION**

guidance **ATTACK THREATS/6 Reconstitution Unit****6. Reconstitution Unit** (See Vol.3-**RS** section)

Facilities must be sized to house the transport vehicles and to provide surrounding space for personnel access, equipment maintenance, and clearance to move the vehicles in and out of the facility.

a. Site location of units

Facilities may be located on- or off-post, as required to reduce the possibility of collateral damage from attacks on the primary targets (such as aircraft, runways, weapon systems, and ammunition dumps). After an attack, survivors must be able to move the equipment out of the shelters and re-establish the DCS communications network. If site personnel are not available to move and operate the equipment, personnel from other locations will be used. The facility should be surrounded by an 8-foot high, chain-link fence with three strands of barbed wire. Cross-overs for drainage ditches are required so that all areas are readily accessible.

b. Design configurations

Transport cabs and trailers can be backed into one long garage or into two side-by-side garages. Also, vehicles can be stored either in a "drive-through" configuration or in a single-access drive that would require "backing-in" for storage. (Rapid mobilization requires all vehicles to be stored "head-out.")

1. Unit types

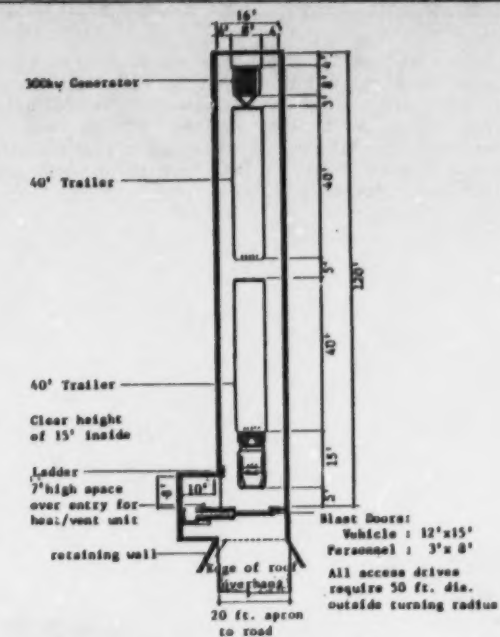
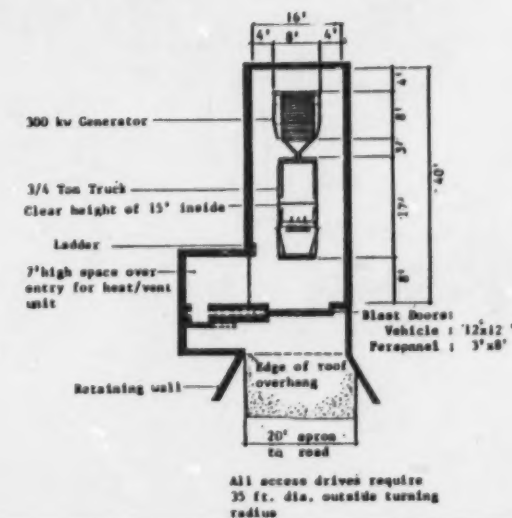
Two types of structures were evaluated as the baseline for a comparative analysis. One is a conventional pre-engineered steel framed building with metal siding designed to protect the equipment from the weather. The other is a standard design, reinforced concrete ammunition igloo with exposed blast doors. Other design considerations are:

No interior columns.

Driveways and other site conditions must be laid out so that any vehicle stored has more than enough turning radius (50 feet).

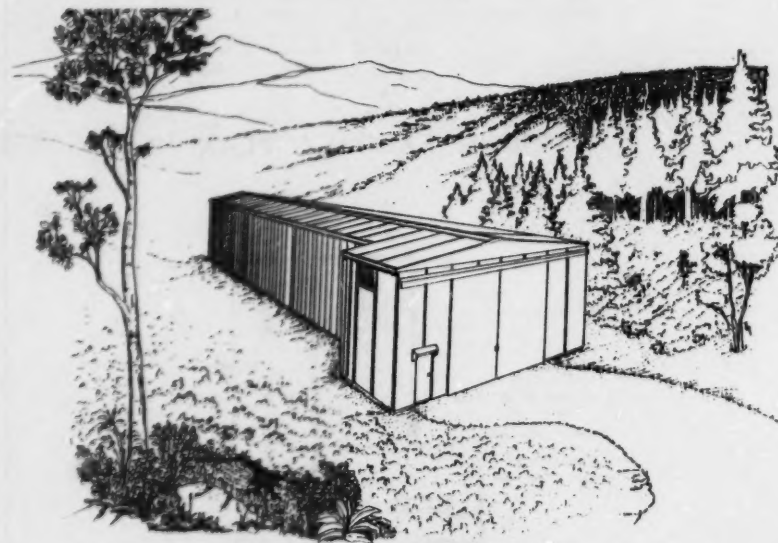
The aquifer characteristics of specific sites will affect the design of the environmental control system and the selection of perimeter ground water drainage systems.

Refer also to "Semi-hardened Contingency Communication Shelters, Vol. 3.

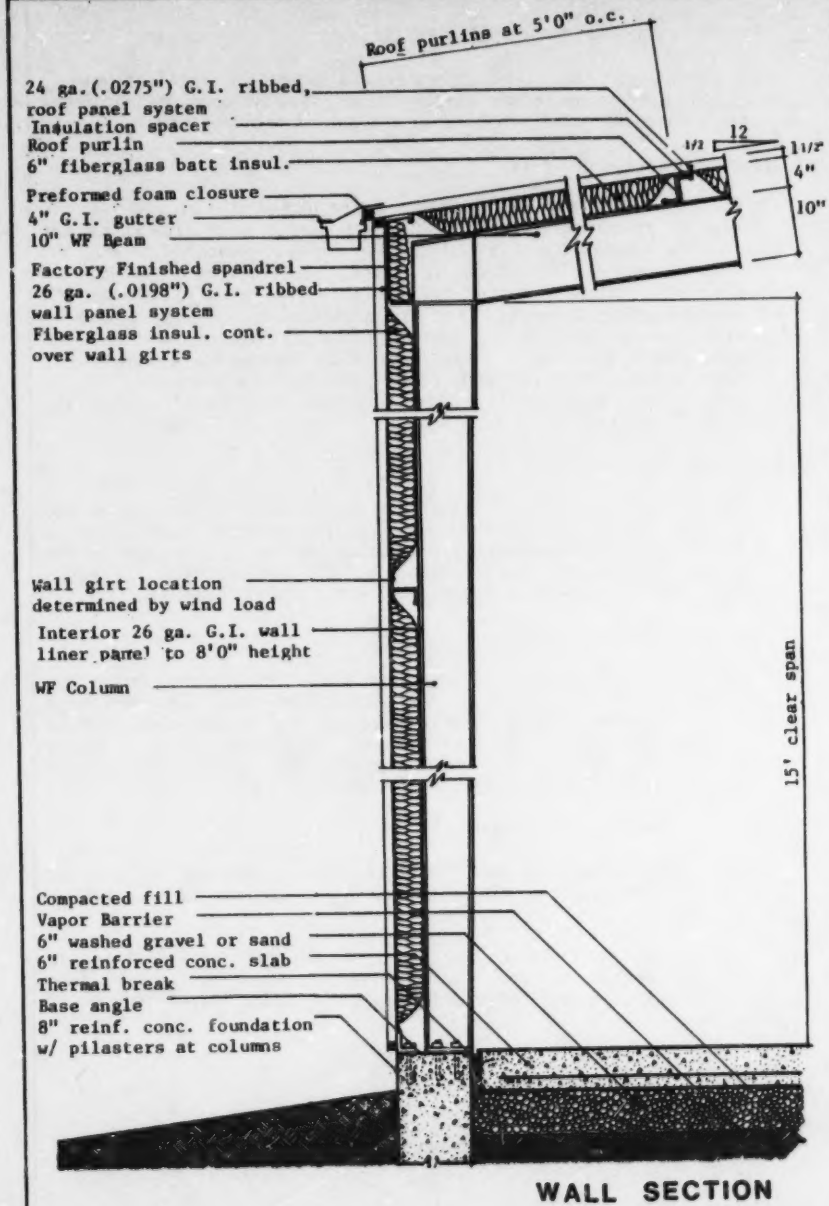
guidance **ATTACK THREATS/6 Reconstitution Unit****TYPICAL FACILITY PLAN**

guidance ATTACK THREATS/6 Reconstitution Unit

The first design type is a low rigid-frame, pre-engineered structural steel building that is manufactured and erected by several firms. The wall covering is 26 galvanized steel panels with a factory-applied finish and 4 inches of fiberglass insulation. Similar panels are used to cover the minimum sloped roof. The foundation and floor slab are reinforced concrete.

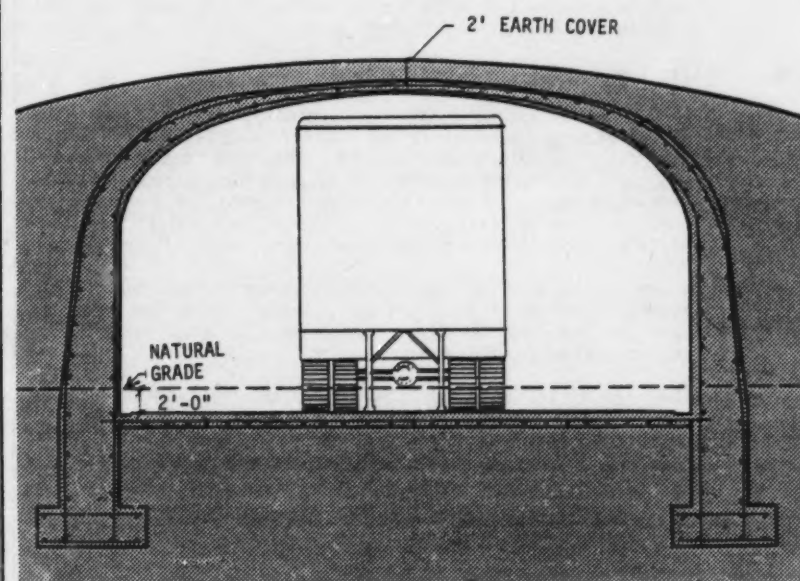
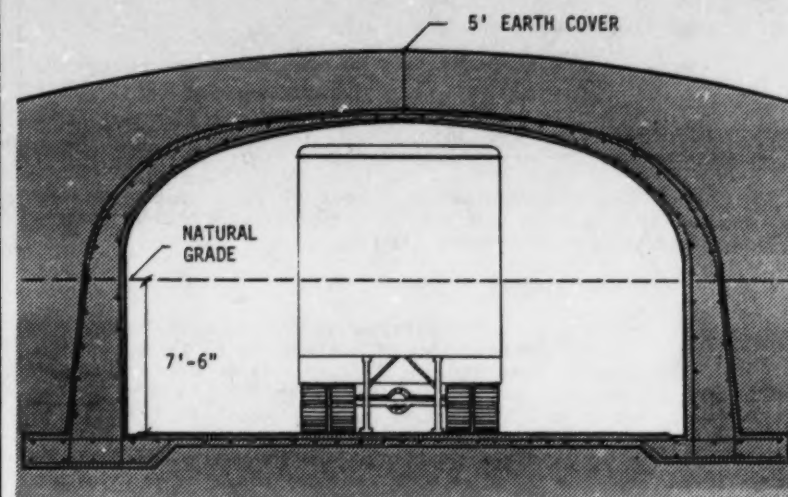
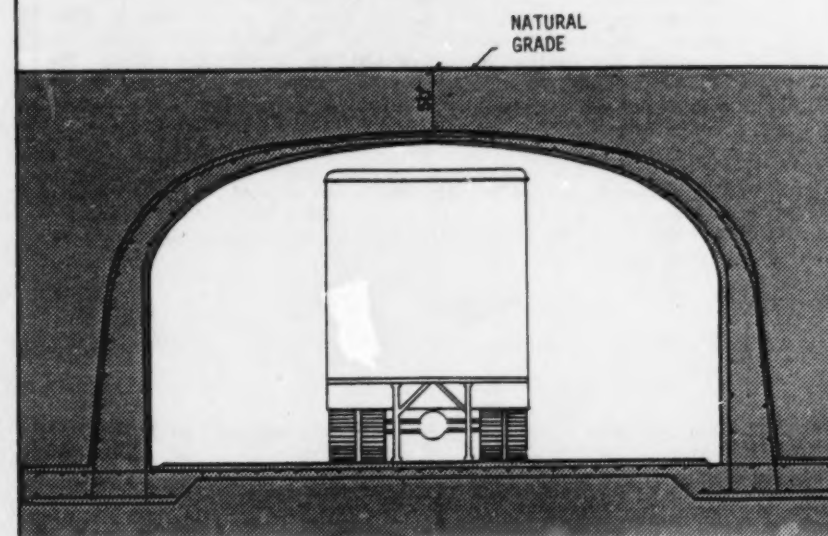


guidance ATTACK THREATS/6 Reconstitution Unit



guidance **ATTACK THREATS/6 Reconstitution Unit**

The second design type, the reinforced concrete ammunition igloo, can have three different siting conditions. In Condition 1, the igloo is constructed on the existing grade and then mounded with a two-foot cover at the top. In Condition 2, half of the igloo is constructed below grade and then mounded with a five-foot cover at the top. In Condition 3, the entire building is constructed below grade, with a minimum 5-foot earth cover at the top. The construction technique is cast-in-place concrete over reinforcing steel using reusable metal frames. The Condition 1 can withstand 7.3 pounds per square inch of blast overpressure, which is equivalent to a 550-pound bomb detonating 94 feet from the structure. Conditions 2 and 3 construction can withstand 5.3 pounds per square inch of blast overpressure (equivalent to a 550-pound blast at 113 feet).

**CONDITION 1**guidance **ATTACK THREATS/6 Reconstitution Unit****CONDITION 2****CONDITION 3**

guidance ATTACK THREATS/6 Reconstitution Unit**C. Size and construction materials**

The facility should be semi-hardened so it can withstand direct hits from at least two high-explosive small artillery rounds and near misses of one or two 500-pound bombs. Such bombs would be falling wide of their primary targets and come near the communications shelters by accident.

There should be no windows. Either one or two blast doors on a hanger-type sliding unit provide personnel access to the stored equipment without opening the blast doors.

d. Mechanical/power systems

Each facility shall have its own mechanical room to maintain the internal environment, provide minimum lighting, and operate the blast doors. Base electrical power will be used during the pre-attack period. However, the facility must be able to operate without base power. Installed equipment must have very high availability/reliability factors. Emergency power could be provided by mobile generation units in areas where several (over eight) facilities are located, rather than having separate emergency generators installed permanently in every facility.

1. Environmental control system

The nature of the storage facility affects the environmental control system in two ways. First, the exterior environment does not affect the interior environment as much because of the insulating effect of the earth cover. Second, limited activities are expected to be performed in the conditioned space. The primary load is assumed to be dehumidification in connection with a storage mode of operation.

Ventilation system and humidity control--Supply a filter to remove dust from the air in the warehouse.

Relative humidity control--95 to 100 percent noncondensing at an ambient temperature of 100°F.

Heating--Low temperature:

Storage transient--50°F

Heater turn-on--50°F

Equipment turn-on--0°F interior ambient with - 25°F exterior ambient

Equipment fully operational--32°F interior ambient with - 25°F exterior ambient

guidance ATTACK THREATS/6 Reconstitution Unit

High temperature:

Storage transient - +155°F

Power air-conditioner turn-on - +125°F

Equipment fully operational - +110°F interior ambient, with +125°F exterior ambient

Special systems--Provide HEMP and CBR control

2. Power system

In keeping with the low energy requirements of a storage function, the intent is to reduce site dependence on commercial powerline availability and to lower operating costs. For this reason, an alternative power system is needed during a conflict. Long shelf lifetime, high efficiency, and minimal exterior air requirements are the qualities desired in such a system.

Lighting--50-lux general light level with 100-volt outlets for adjustable lights (for parts installation and/or inventory).

Maintenance--110 volts for maintenance and tools, 20 feet on center throughout the storage area.

e. Facility constraints

1. DCA has placed communication equipment in Europe for use in reestablishing communications after hostilities begin. Facilities are needed to give more protection to the equipment than currently being provided in motor pools, warehouses, and aircraft hangars. Since survivability cannot be ensured, DCA wants to develop facility information that relates various levels of protection provided to various levels of cost.
2. No provisions will be made for housing personnel. During an attack, if personnel are present, space around the vehicles could be used for shelter, but providing continuing life-support systems is not required.
3. Site security would be external to the facility and installed/monitored by others.
4. The communication equipment need not operate in the facilities during the attack period. There is no secondary mission for the facilities after the vehicles have been removed.
5. Remote monitoring and management of the installed equipment should be available.

guidance ATTACK THREATS/7 Protective Design

6. Above-ground power source components are acceptable in base power backup system. No effort will be made to camouflage the facilities' location, and exposed components should be considered sacrificed during the attack.

7. Protective design

How much to provide in the various defense structures is an important item, one that will require superior judgment to establish proper criteria. The maximum protection must be provided against the most likely weapon(s) to be used against the installation at the most economical expenditure of cost and effort. The protection provided by a structure must meet all conditions of attack from the weapon(s) selected, and therefore the roof, walls, and floor must provide equivalent protection against the most severe conditions of attack. (184) 4-1

a. Protection against direct hits

1. Bomb-resistant construction

A bomb-resistant structure is generally designed to provide protection from all types of bombs (armor piercing, semiarmor piercing, and general purpose) of a specified weight. Bomb-resistant construction also provides an equivalent degree of protection from artillery fire, shaped charges, demolition charges, and so forth.

2. Types of structures that may be used

Surface structures--Structures built entirely above ground allow for convenient arrangement of the installations and avoid waterproofing complications. The walls may be considerably thinner than those required for buried structures. However, it is almost impossible to conceal a large installation, and camouflage discipline will be more difficult to maintain. Surface structures are also very vulnerable to all types of ground attacks.

Buried structures--Many types of buried structures can be adapted to various terrain features, and they give excellent protection from bombing and artillery fire. Deeply buried tunnels are excellent for operations and control facilities and for storing vital equipment and supplies. Buried structures are adaptable for concealment and are extremely resistant to all types of attacks except the buried explosion of heavy bombs. Air shafts and entries will be vulnerable, and special care must be taken in planning of these areas. An integrated system of underground structures linked by communication tunnels will present a formidable defense.

guidance ATTACK THREATS/7 Protective Design

3. Protective thickness of materials

Roof design--The roof of a direct-hit bomb-resistant structure must resist perforation by all bombs of specified weight (the AP and SAP types are generally considered, not the GP type, which tends to deform upon striking the concrete). The roof must also resist projectiles of similar weights. Bombs striking at terminal velocity will generally have such great obliquity that a ricochet will occur. Antiscabbing plates (securely anchored) or steel beams with plates laid on the bottom flanges should be part the roof design of control rooms and in areas housing personnel and equipment. The steel beam-plate method is preferred because the beam and plates serve as supporting roof forms. If plates are not used, an additional 15 percent of concrete thickness should be added to prevent scabbing or spalling of the concrete ceiling. The same general procedure should be used for penetration of projectiles. (184) 4-4

Wall design--The thickness of the reinforced concrete walls is based on projectile penetration and on the explosion of bombs detonating on the surfaces and near the sides of the wall. Protection against projectiles and application of antiscabbing plates are as described above. (184) 4-6

4. Protective floor design

Besides supporting dead and live loads, the floor must also resist the force of underground explosions. Floors become vulnerable to heavy bombs when the bombs follow a curved path that places them just beneath a floor. Artillery shells may also detonate under the floor slab, but less damage would be expected because of the smaller weight of the charge. If the design analysis indicates that a thinner floor could support static loads, the thickness of the slab may be decreased by using footing or burster slabs or rock rubble/boulder screens. (184) 4-6

5. Rock-rubble/boulder screens and burster slabs

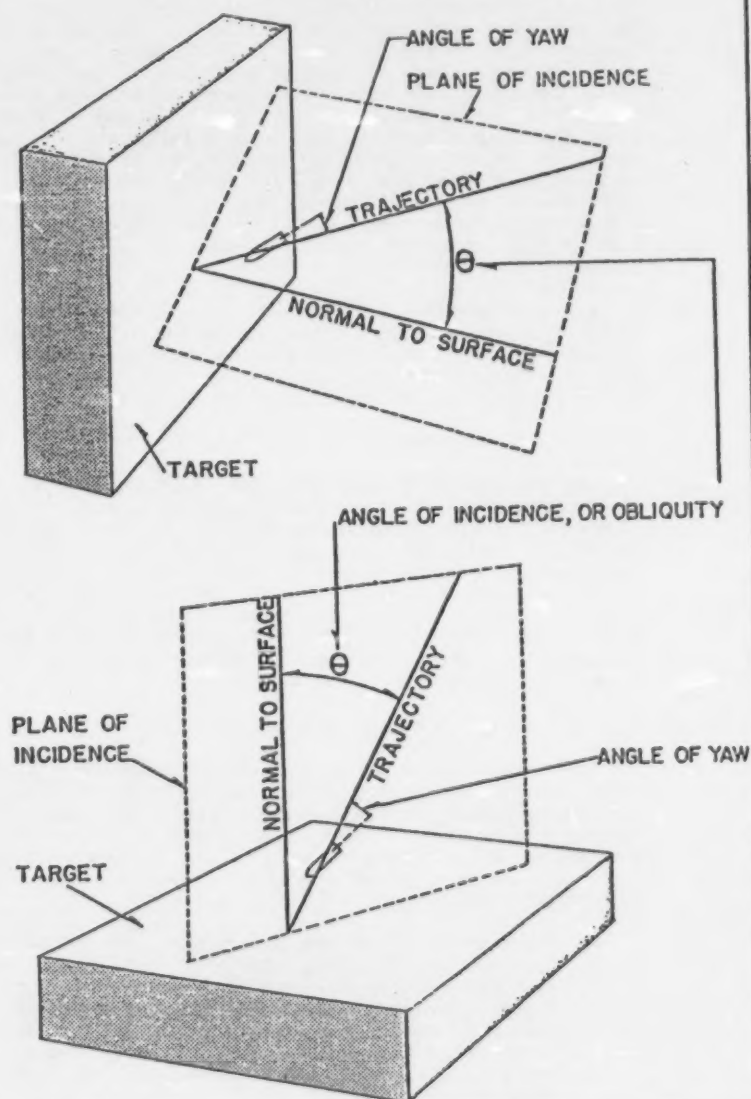
This system is used in buried structures when a high degree of protection from aerial bombing must be provided. The function of the screens and the burster slabs is either to destroy the incoming projectile at impact or to reduce its penetration depth and hence increase the explosion standoff distance. Penetration of a projectile into a dense medium depends on: (185) 7

- a. Characteristics of the projectile, such as weight, caliber or diameter, length, nose shape, and structural integrity of the projectile (such as rigidity and wall thickness). (Caliber refers to the boulder diameter. For example, a two-caliber boulder means that a boulder screen has a nominal dimension of approximately twice the diameter of the expected projectile.)

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- b. Striking conditions such as impact velocity, angle of incidence, and yaw (see the following figure).

GEOMETRY OF IMPACT.



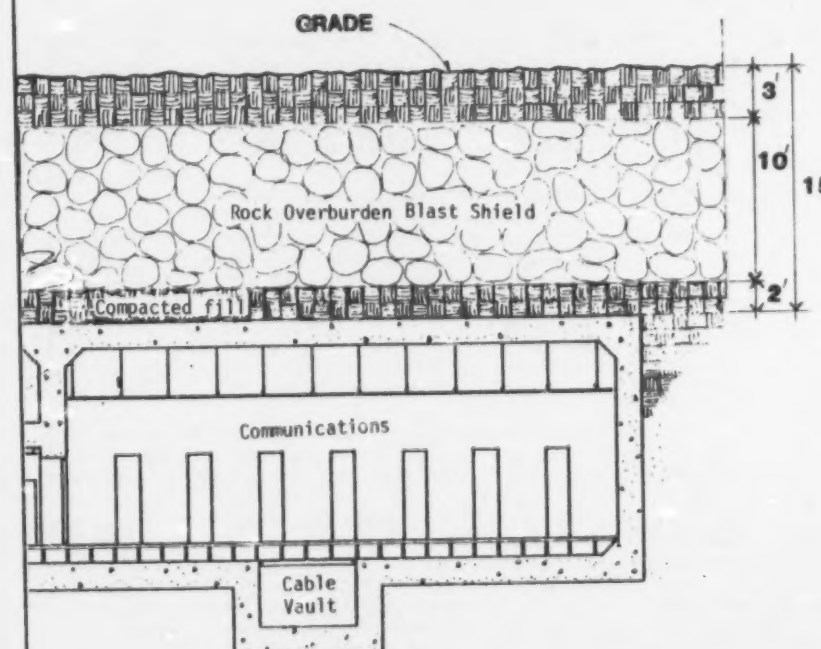
guidance ATTACK THREATS/7 Protective Design

- c. Properties of the target material, such as strength or hardness, density, ductility, and porosity.

In general, depending on the interaction of all these variables, any of the following situations could occur when a projectile strikes the target:

- Break-up, significant deformation, or defeat by the target.
- Ricochet or broach.
- Penetration into the target.

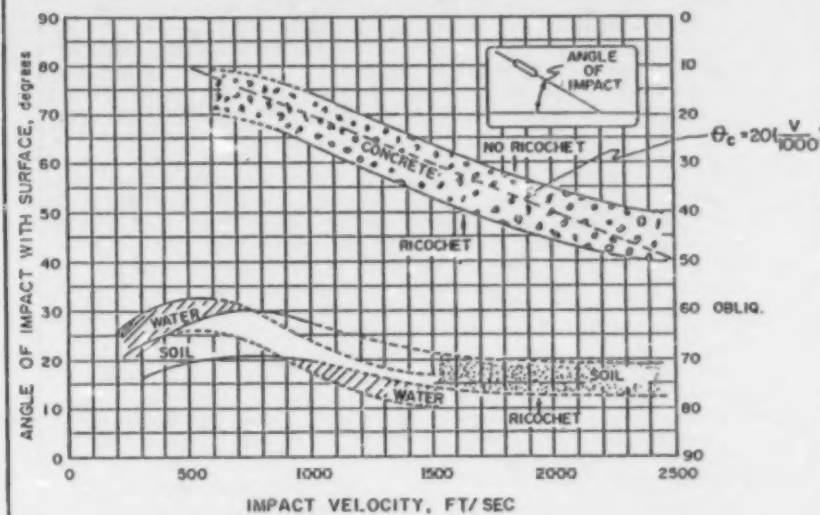
BLAST SHIELD PROTECTION.



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Angles of yaw on the order of several degrees could cause a projectile to break up when it hits a hard target. As the angle of obliquity increases, the probability that a projectile will ricochet when it hits a hard target also increases (see the following figure). (185) 8 If the projectile can be rejected by the protective system, the thickness of the protective layer can be greatly reduced, resulting in substantial savings. Also, the magnitude of shock levels transmitted to the target will be drastically reduced because of the increased standoff distance.

EFFECT OF IMPACT VELOCITY AND OBLIQUITY ON RICOCHET.
(Ralph M. Parsons Co. 1968)

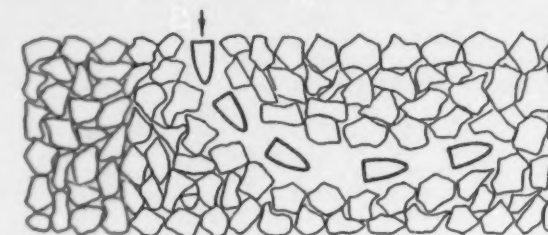


The following basic mechanisms are believed to be involved in defeating the projectile: (185) 9.

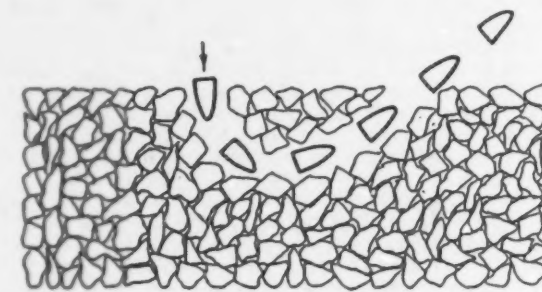
As the projectile tries to pass through the rock matrix, there is a high probability that several of the impacts will not be normal. This will induce large obliquity and yaw angles, causing the projectile to either deflect from its initial path, ricochet or broach, or break up (see the following figure). The angularity of the boulders will be an important factor for such a mechanism. Also important will be the presence of a sufficient air space in the rock matrix.

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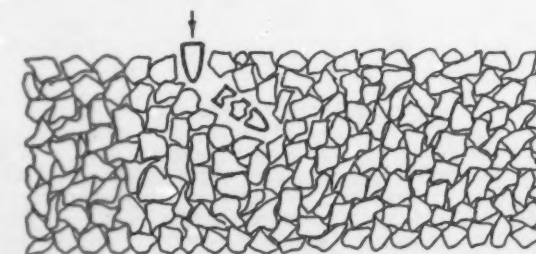
POSSIBLE MECHANISMS OF DEFEAT ASSOCIATED WITH ROCK RUBBLE/BOULDER SCREENS.



a. Path deflection.



b. Ricochet or broach.



c. Projectile failure and breakup.

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Penetration through the rock matrix is not a continuous process. The projectile may disintegrate or pulverize the first pieces of rock it encounters and continue penetrating through the broken materials until it hits the next rock surface. This may be viewed as the beginning of a new penetration process, resulting in a sudden increase in the stress field resisting the motion of the projectile. This discontinuity in the stress field will, in general, promote projectile rotation, resulting in the same mechanisms of defeat shown in the figure. The thickness and the packing arrangement of the boulder field will affect penetration.

Because of the discontinuous or particulate structure of the rock matrix, part of the momentum of the projectile will be expended in moving the individual boulders in various directions, probably randomly. This process will also reduce the penetration capability of the projectile. The mass of the individual boulders (relative to the mass of the projectile) will, of course, affect this process.

In any particular case, the most important mechanisms of defeat depend on the characteristics of the particular weapon and of the boulder screen. In the case of slender projectiles (a length-to-diameter ratio of about 10 or more), the dominant mechanism of defeat is probably failure due to bending. On the other hand, in the case of projectiles with low length-to-diameter ratios (such as most SAP-like weapons), which are inherently unstable, the weapon is likely to rotate significantly and tumble in the boulder field. (185) 10

A research program at the U.S. Army Corps of Engineers Waterways Experiment Station (WES) evaluated the potential of rock-rubble/boulder screens for defeating air-delivered weapons. (185) 10 Tests were performed using diorite boulders with a compressive strength of 32,000 pounds per square inch. The results show that for the 2- and 3-caliber boulder screens, the projectile turned considerably after penetrating into three to four layers of boulders. That is, the projectile either slid against the target concrete or bounced back and tumbled in the boulder field. (185) 13 At least in this case, five layers of 1-caliber boulders appear to provide the same degree of resistance to penetration as two layers of 2-caliber boulders. (185) 14

Rock-rubble/boulder screens are useful parts of protective systems against penetrating weapons. Because of the distinctive nature of the boulder screen, such a protective system can easily be upgraded for additional protection against future threats. The system also protects against repeated hits and can be repaired easily and quickly after it has been attacked and damaged. Adherence to the following guidelines is necessary to realize the benefits of the rock-rubble/boulder screen for defeating (or degrading the penetration capability of) penetrating weapons: (185) 21

guidance ATTACK THREATS/7 Protective Design

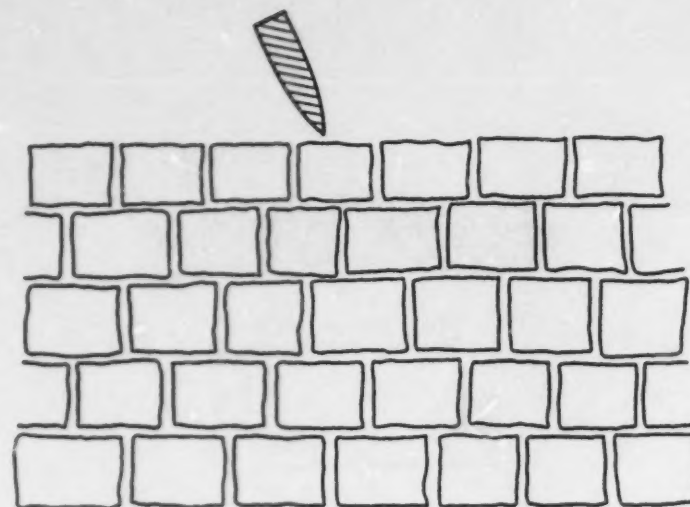
Use hard rocks having compressive strengths of over 30,000 pounds per square inch. The boulders must be free of joints, fractures, or other flaws.

Flat plate-like boulders should be avoided. The aspect ratio of the boulders (the ratio of the largest to the smallest dimension) should not exceed 1:3.

The boulder screen should be thicker than the projectile is long. In the case of short length-to-diameter SAP-like weapons at an impact velocity of 1000 feet per second, experimental data indicate that four layers of 2-caliber boulders underlain by a thin slab of concrete would defeat the weapon (i.e., the weapon would turn considerably and would not be able to perforate the protective system). As a preliminary guide, the thickness of the slab should be about 1 caliber. Slender projectiles (with a length-to-diameter ratio of approximately 10 or more) will experience severe bending deformations during penetration into a 2- to 3-caliber boulder field with an overlay thickness greater than the length of the projectile. Such bending deformations could result in breakup of the projectile.

Several arrangements can be used for the construction and packing of the boulder screen, depending on the application. At one extreme, the boulders can be shaped like blocks and then placed by hand to simulate an artificially jointed rock layer (see the figure). This type of arrangement reduces the velocity of the projectile but does not induce projectile rotation. It is also expensive to construct. The other extreme involves randomly shaped boulders dumped by truck (see the figure). Because of the irregular shape of the boulders and the ample void space between them, this kind of arrangement induces projectile rotation and tumbling. This arrangement is also cheaper to construct than the hand-placed block boulder arrangement. However, it is not as effective as the hand-placed block-type boulder screens in reducing the velocity of the projectile. To take advantage of the capability of this type of boulder screen to induce projectile rotation and to reduce penetration, a combination of a few layers of truck-dumped randomly shaped boulders and a thin slab of concrete would be most effective for defeating a projectile (see the figure). This is particularly true in the case of short length-to-diameter SAP-like weapons (see above). The boulders will induce projectile rotation and the concrete slab will deflect the path of the projectile, causing it to broach or ricochet, thus increasing the explosion standoff distance.

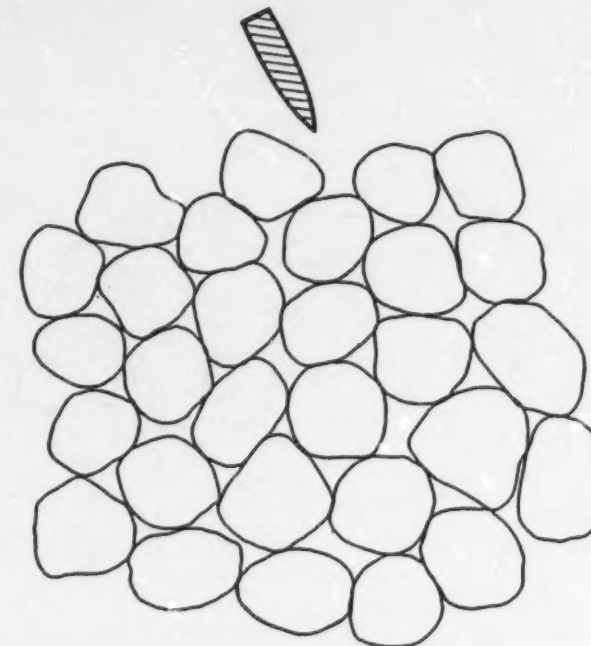
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- CONTROLLED HAND-EMPLACED BOULDER SCREEN
- SIMILAR TO AN ARTIFICIAL JOINTED ROCK LAYER
- EFFECTIVE FOR REDUCING THE VELOCITY OF THE PROJECTILE
- NOT VERY EFFECTIVE FOR INDUCING PROJECTILE ROTATION
- EXPENSIVE TO CONSTRUCT

HAND-EMPLACED BLOCK-TYPE BOULDER SCREEN.

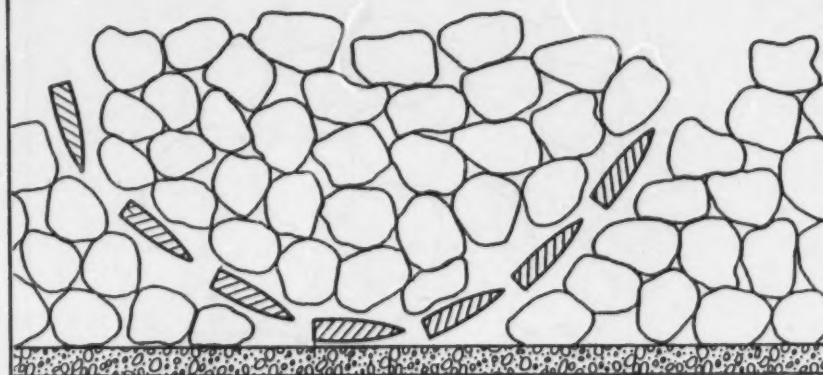
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- RANDOMLY SHAPED TRUCK-DUMPED BOULDERS
- NOT VERY EFFECTIVE FOR REDUCING THE VELOCITY OF THE PROJECTILE
- EFFECTIVE FOR INDUCING PROJECTILE ROTATION
- LOW-COST CONSTRUCTION

TRUCK-DUMPED RANDOMLY SHAPED BOULDER SCREEN.

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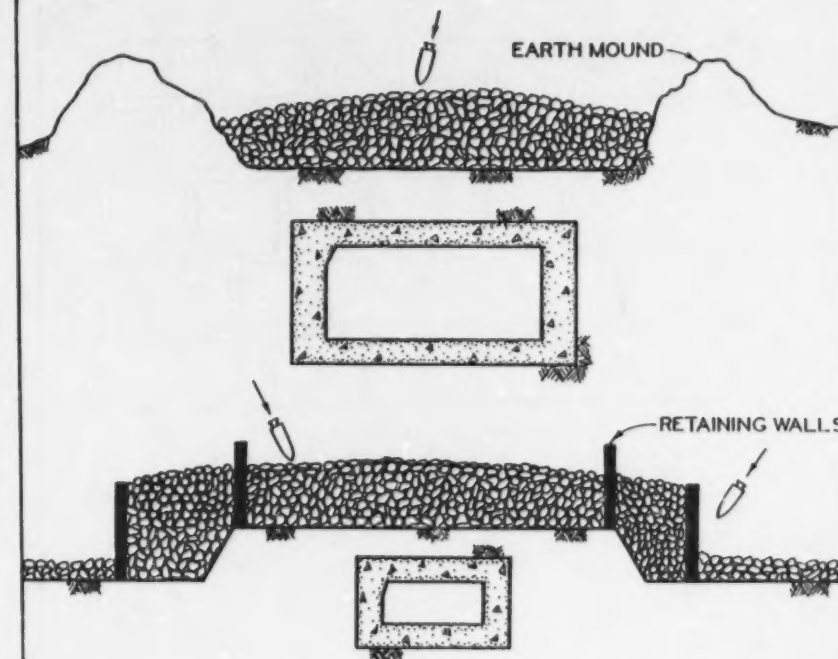


- COMBINATION OF FEW LAYERS OF TRUCK-DUMPED BOULDERS AND A THIN CONCRETE SLAB
- BOULDERS WILL INDUCE PROJECTILE ROTATION
- CONCRETE SLAB WILL DEFLECT THE PATH OF THE PROJECTILE, THUS INCREASING THE EXPLOSION STANDOFF DISTANCE
- EFFECTIVE FOR LOW L/D LARGE SAP WEAPONS

COMBINATION OF TRUCK-DUMPED RANDOMLY SHAPED BOULDERS AND CONCRETE SLAB.

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The boulder screen should be confined to prevent excessive lateral motion of the boulders. Confinement can be provided by an earth mound, concrete retaining walls (see the following figure), or similar means.



POSSIBLE MEANS FOR PROVIDING CONFINEMENT FOR A ROCK-RUBBLE/BOULDER FIELD.

guidance ATTACK THREATS/7 Protective Design**6. Special design requirements (184) 4-6**

Working stresses--Conventional static loads, dead and live, may have to be supplemented by the effects of impulsive loadings due to impact and explosion. In most cases, however, design based on static loads is adequate.

Reinforcement--Enough reinforcing bars must be provided to withstand the static load stresses and to knit the concrete together under the forces from impact and explosion. The steel should be of intermediate grade; deformed bars are recommended.

Form of structure--Slabs and partitions with uniform sections are preferred. Beams, girders, and other elements with heavy load concentrations are less satisfactory and are uneconomical from the standpoint of protection. Outside edges of concrete structures should be rounded, if practical, to minimize the probability of normal impact and to increase the chance of ricochets. Sharp outside edges are badly spalled by impact near the edge and attrition is greater as a result of spalling caused by fragments. Entranceways should be offset or baffled to provide maximum protection in the event of a near-miss.

Joints--There should be a minimum number of construction joints. Keyways and dowels should secure the joints under the various impulsive loads; they should conform to standard practice except that the dowels should be lapped 50 bar diameters. Contraction or expansion joints should be used in large structures in accordance with standard practice for reinforced concrete structures. Klaterstops may be required for expansion and contraction joints. Buried structures may be provided with a contraction joint only wide enough so that it can be poured after adjoining monoliths are completed.

Interior partitions--Should be able to resist confined blast and fragments if a bomb penetrates the structure during a concerted attack.

b. Protection against near misses

In many cases the functional importance of a structure--its size and location relative to larger or more important structures--will not justify the expense and use of materials for bomb-resistant construction. In such cases it is necessary only to provide a certain degree of lateral and overhead protection against blast and splinters of a bomb of specified size detonating at a nominal distance from the structure. An economical degree of protection has been developed on the basis of a 500-pound GP bomb detonating 25 feet away. The thickness of material resulting from this criterion permits good construction practice and maximum structural stability with minimum materials. Tests indicate that these prescribed thicknesses were not completely proof against

guidance ATTACK THREATS/7 Protective Design

fragment perforation at 25 feet; however, they are 95 percent effective. Proof protection may be reasonably assumed at 35 to 40 feet from a 500-pound GP bomb with these thicknesses, normally an economical degree of protection. It has been observed that structural collapse seldom occurs if a bomb falls more than 15 to 20 feet from a steel- or concrete-framed structure. Blast and splinter resistant structures should be given overhead protection against perforation of incendiary bombs and the effects of debris resulting from explosions. (184) 4-8

1. Protective thickness of materials

Thicknesses adequate for protection against all types of bombs at a distance of 40 feet are shown in the following table. These thicknesses give 95 percent protection at a distance of 25 feet, provided that structural continuity and good quality construction are maintained. (184) 4-8

REQUIRED THICKNESSES OF MATERIALS TO PROTECT AGAINST FRAGMENTS AND BLAST OF BOMBS OF ALL TYPES AT A DISTANCE OF 40 FEET (IN INCHES)

Reinforced Bomb	Mild steel	concrete	Reinforced concrete	Plain brickwork
100-pound	1 10		14	13-1/2
250-pound	1-1/2		12	16 13-1/2
500-pound	2 12		18	17
1,000-pound	2-1/2	16	22	21-1/2
2,000-pound	3	20	28	25

Bomb	Plain brickwork	Precast concrete block	Earth-filled crib	Sandbags
100-pound	13-1/2	16	20	24
250-pound	17	20	24	30
500-pound	21-1/2	24	30	36
1,000 pound	25	28	36	42
2,000 pound	28-1/2	32	42	54

2. Recommended clear distances between structures

Structures with walls of the thicknesses given in the above table should be spaced at a minimum clear distance of 50 feet.

Ordinary wood-framed or brick load-bearing-wall buildings should be dispersed as much as possible, preferably at minimum clear distances of 120 feet.

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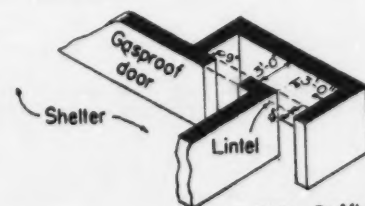
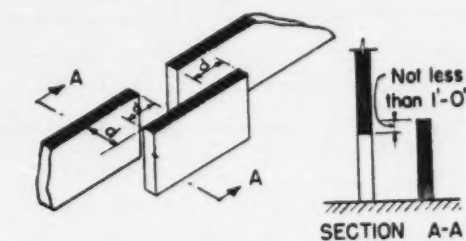
3. Design considerations

Buildings should be framed structures of steel or reinforced concrete, with emphasis placed on maximum continuity to prevent spreading collapse if one or two supporting members are displaced. Framed structures designed to withstand seismic loads are not seriously affected by earth movement or shock from bombs exploding at distances over 40 feet. Brick buildings with load-bearing walls do not resist the effects of bombs.

Wall with thicknesses given in the above table will be able to withstand the blast effects from all bombs of specified weights, and at specified distances. The exception may be certain types of light-case or high-capacity bombs, or types with special explosives which tend to produce greater blast damage. Walls or wood frame construction, while not resistant to splinters in the usual thicknesses, collapse by blast more than walls of brick load-bearing construction do. (184) 4-9

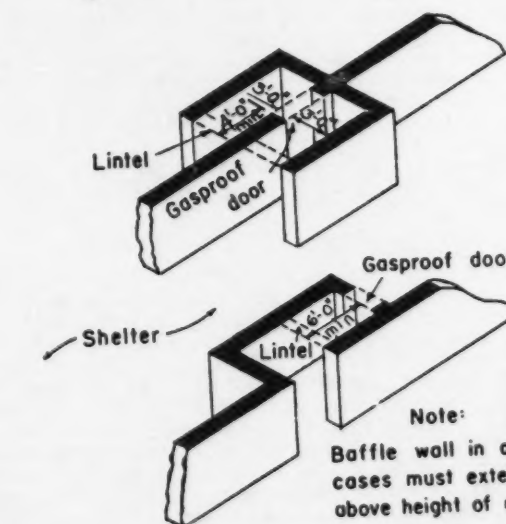
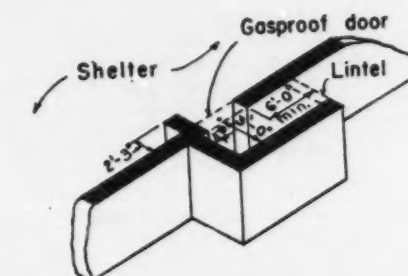
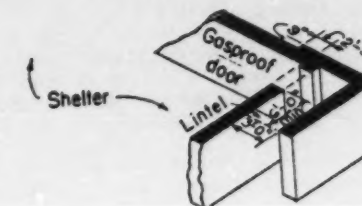
All material used as overhead cover should be properly supported and secured to other elements of the structure. All overhead protection for structures entirely or partly above ground should be able to resist upward thrust which might result from a nearby blast. For this reason, continuity of design and secure fastening of structural members to each other is important.

As illustrated in the following two figures, all entrances should be protected with baffle walls where feasible.



Note: Baffle wall in all cases must extend above height of opening in Section A-A

guidance ATTACK THREATS/7 Protective Design



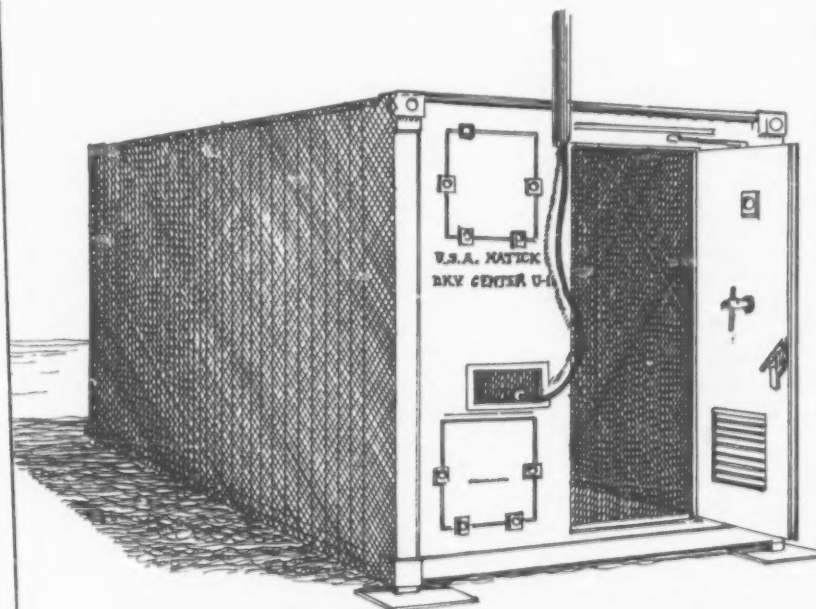
Note:
Baffle wall in all cases must extend above height of opening

guidance ATTACK THREATS/8 Hardened Shelters

8. Design considerations

The U.S. Army is developing a family of "hardened" transportable tactical communications equipment shelters. These shelters, resistant to 7 psi overpressure, will significantly improve survivability to shrapnel, nuclear blast, and thermal effects. They will also provide a suitable shielded structure for implementing terminal protection for DCS communications functions. The size of these hardened shelters makes them appropriate for rapid bunkering or use in caves and tunnels. The shelters are modular and rapidly transportable/recoverable.

A recent shelter development with obvious potential for use in the 1990s by DCS is the ISO (International Organization for Standardization) container. This container may be shipped as an 8-by-8-by-20-foot package anywhere in the world. It comes in a rigid, nonexpandable model, in 3-to-1 and 7-to-1 expandable models, and as a hangar-style archway cover. The ISO container also has been RFI/EMI shielded to 74 decibels. There are plans to use lightweight high-impact KEVLAR material to provide blast and shrapnel protection. (KEVLAR is the brand name of an aramid fiber manufactured by E. I. Dupont Corporation.) (182) 4-22



guidance CBR THREATS/1 Building Protection

1.a. Exterior surfaces resistant to contamination

The resistance to contamination of an exterior building component depends on qualities of the outer envelope, or "skin."

1. The exterior envelope should be an essentially continuous skin, impervious to chemical-biological warfare agents.
2. Exterior envelope finishes must resist the effects of standard decontaminants, such as DS-2, STB, hot soapy water, germicidal soap, and 5 percent washing soap solution.

The design of shelters should provide for the decontamination of areas which have been exposed to CBR agents. Special concern are the entrances contaminated by direct attack with CBR agents and the entrances and decontaminating facilities contaminated by exposed personnel and equipment. (91) 45

The most versatile decontaminant is water. Water, or water with detergents added, is used to remove most CBR agents from smooth, nonporous surfaces. Water alone, however, does not neutralize the effects of most contaminants. The use of fog nozzles rather than standard hose nozzles minimizes the possibility of water splashing and spreading contamination to clean surfaces. Steam may be more efficient for removing greasy substances that have been contaminated or for purging porous surfaces. Radioactive warfare (RW) contamination must be removed and the wash residue carefully disposed of. Neutralization of contaminants is more specialized and only effective for chemical (CW) and biological warfare (BW). (91) 47

Like radiological contamination, biological contamination is a surface condition. Unlike radiological contamination, however, it can be destroyed or neutralized. The preferred methods of decontamination of biological agents are by chemical disinfectants and heat. (91) 62

No one chemical is a completely ideal decontaminant because none is effective as well as noncorrosive, nontoxic to personnel, and easy to handle and apply. (91) 62

b. Openings protected from contamination

1. Air lock entry for personnel - Probably as part of a decontamination station (see the following section, "Decontamination Station").
2. Waveguide entry and exit ports.
3. Cable entry and exit ports.
4. Power supply entry panels.
5. Exhaust pipes (such as in a kitchen) and vent ducts.

guidance CBR THREATS/1 Building Protection

c. Air circulation system

Air distribution

For maximum benefits from a minimum quantity of filtered outside air or to prolong the occupancy time in a structure deprived of a fresh air supply, a proper air distribution, circulation, and recirculation system should be designed.

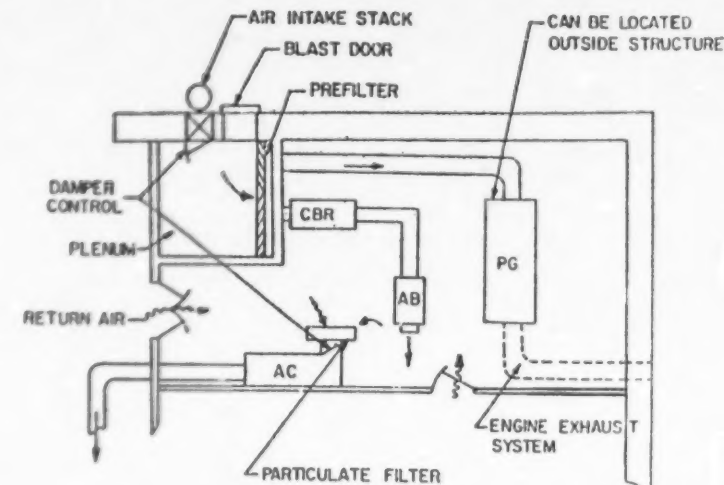
The location of combustion engines and other air-consuming equipment is also very important. Such equipment will be provided with a closed system of unfiltered air, or will be so located within a structure that filtered air required for personnel will exhaust through the equipment area and be used for combustion. Because of the possibility of occupying a structure without benefit of fresh air, any equipment depending on the exhaust air for combustion would soon create an untenable condition within the structure. Therefore, it is recommended that such equipment be isolated and provided with its own air supply and exhaust.

Filtered air should be distributed so as to eliminate "dead air" pockets and provide uniform air quality for occupants. It is recommended that a duct system for air distribution be used wherever feasible, except between areas or rooms where pressure differences are to be maintained. In protected structures that do not warrant extensive duct systems, the distribution of air between rooms may be accomplished by the differential-pressure method used in the air locks. In structures without central air-conditioning or air-handling equipment, circulation or recirculation of air can be obtained by the proper placement of floor or wall fans. During emergency periods when filtered air cannot be supplied in such a structure, air can be recirculated by a dampered opening in the connecting duct between the filter units and the supply fan. This continued recirculation of air will extend the occupancy time in most cases (Chemical Systems Laboratory (CSL), Aberdeen Proving Ground, MD (APG)). (90) 22, 23

A contaminant-free air supply is the most critical requirement for a collective protection system. The filtered air supply to the decontamination station and the main shelter may be completely recirculated, partially recirculated, or completely vented. (166) 9

Outside air should enter the protected facility through an air intake blast closure if the shelter can withstand blast pressures. The blast closure protects against momentary excessive pressures which could damage the filters. After passing through the blast closure, the air enters a plenum chamber, if required. From the plenum chamber, the air should be passed through prefilters, particulate filters, gas filters, and then through a central air conditioner, if available. The filtered air should be distributed through the

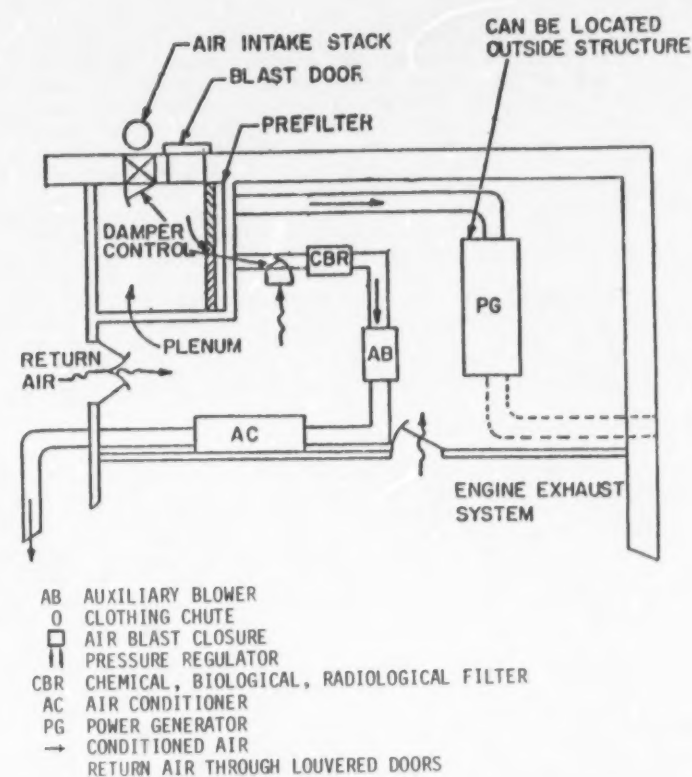
guidance CBR THREATS/1 Building Protection



- AB AUXILIARY BLOWER
- CLOTHING CHUTE
- AIR BLAST CLOSURE
- || PRESSURE REGULATOR
- CBR CHEMICAL, BIOLOGICAL, RADIOLOGICAL FILTER
- AC AIR CONDITIONER
- PG POWER GENERATOR
- CONDITIONED AIR
- RETURN AIR THROUGH LOUVERED DOORS

RECIRCULATION THROUGH A PARTICULATE FILTER AND AIR-CONDITIONER.

guidance CBR THREATS/1 Building Protection



RECIRCULATION THROUGH THE COMPLETE CBR FILTER SYSTEM.

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building so that it flows from the working or active areas to the remaining personnel areas and then returns to the mechanical room. Air which has passed through toilets or kitchens should not be recirculated through the ventilating system unless it has been filtered to remove objectionable odors. The following figure shows recirculation through a particulate filter and the air-conditioner, with makeup air passing through the CBR filter. The next figure shows both recirculation and makeup air passing through the complete CBR filter system. The latter method of filtration is the optimum design because it minimizes the possibility of covert dissemination of contaminants within the shelter by a saboteur. As a third possibility, the recirculated air can be passed through separate particulate filters and commercial gas filters and mixed with CBR-filtered makeup air before entering the air-conditioner. (166) 9

Regardless of the air supply system used, the controlled air flow leaving the decontamination station should be vented through an anti-backdraft valve and finally through an exhaust blast closure if the shelter is designed to withstand blast pressure. (166) 9

d. Prevention of HVAC system contamination

The building HVAC system requires two levels of contamination protection: (1) the prevention of chemical intrusion into the air intake ducts, and (2) enough air circulating in the system to prevent infiltration of chemicals through cracks in windows and doors.

1. Automatic back dampers on all intake and exhaust ducts along with an automatic chemical alarm in the main ventilation duct
2. Positive overpressure to ensure exfiltration through the window and door cracks

e. Maintenance of noncontaminated water supplies

1. Daily supply

The water source for most DCS sites is the local community water system. When the water pressure cannot meet the requirements of the site, a pumping station is used to obtain the required residual/static pressure and flow. (80) A-8

Since control over the water source cannot be supervised, chemical and biological protection is required. The simplest way to provide this protection is to require military personnel to use bottled water for drinking and cooking. The M-2 water test kit would be used to test for chemical agents in bottled water. At present, no universal test exists to determine if different types of biological agents exist in a water supply. Buying water from different suppliers would minimize its probability of being contaminated. (89) A-9

guidance CBR THREATS/1 Building Protection**2. Reserve system**

A pressurized tank system with booster pumps should be used. The tank should be located in a concrete structure below the floor of the clean mechanical room if space is not available in the room.

The amount of water stored is based on 105 liters a person for a "button-up" period plus a specified amount for decontamination of people and resupply items, including equipment decontamination requirements (provided in supplements to these criteria). Water consumption by automatic fire sprinklers and equipment should be included.

A closed type refill system will prevent contamination of the water. A water tank or trailer will be used for water resupply. Supply and venting line connections compatible with a truck hose are to be included. A purge capability shall be incorporated. The water truck connection point is best located in the dirty mechanical room.

In the event of NBC (CBR) attacks, there should be a backup system to ensure safe drinking water for the inhabitants of the DCS sites. The current Army practice in the field use is to use ROWPUs (Reverse Osmosis Water Purification Units) to remove such hazards. These devices, developed by MERADCOM (Mobility Equipment Research and Development Command), are available in a 600 gallons per hour model. A 3000 gallons per hour unit is being designed. These units can clean up nearly any problem, including turbid water, brackish water, seawater, and chemical, biological, and radiological agents. They can remove over 99 percent of contaminants, which may reduce the contamination level to below the maximum permissible concentration. The treatment consists of the following steps:

- Addition of coagulation (polyelectrolyte)
- Clarification
- Multimedia filtration (coal, sand, garnet)
- Five-micron filter cartridge
- Reverse osmosis membrane
- Granular activated carbon bed
- Chlorination with 5 to 10 milligrams per liter free available chlorine.

This treatment, with its redundancies, can remove the offending materials and produce potable water. Care must be taken that the initial water is not so overloaded that even with 99 percent removal, the chemical agent is still toxic.

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A ROWPU unit should be available to the DCS site in a protected area able to tie in quickly to the water source. Enough personnel should be trained to operate and maintain it during emergencies.

3. System survivability

See TM 5-225, Radiological and Disaster Recovery at Fixed Military Installations, for discussions of the effects of nuclear weapons on water and wastewater treatment plants and their restoration following attack. Physical damage may occur from the direct effects of blast overpressure and ground shock, thermal radiation, and initial nuclear radiation. Equipment inside a DCS building would already be protected due to the hardening for protection of C-E equipment. Flexible connections may avoid major damage for aboveground connections. Underground mains and tunnels would probably be left in good condition. Electricity consumers such as pumps and motors are generally heavily constructed and will not suffer structural damage. However, protection should be provided against electric overloads in unshielded areas, such as offsite wells. The other major hazard, fallout, can be cleaned out of drinking water by a ROWPU. Fallout should be prevented from entering the plant through security measures.

4. Contamination disposal

Wastewater contaminated by CBR (NBC) agents does not usually get any special treatment. Since its use occurs during hostile conditions, it should be disposed of the most expediently. An example is dumping the wastewater into a nearby river or digging a lagoon and filling it with dirt following liquid disposal. Containerization with transport to a national graveyard is another alternative, but is generally impractical.

Sources of contaminated wastewater include decontamination activities and ROWPU brine wastewater.

2. a. Decontamination station layout design

Decontamination facilities are required so that personnel can safely enter a protected structure from a contaminated area. In all CBR-protective structures, to which personnel are permitted limited exit and entry, provisions will be made for personnel to enter safely through a decontamination facility. (90) 12

Entrances to protective structures will be designed for exit and entry both during periods of operation when attack is not imminent and during periods of attack. This will eliminate the everyday use of the decontamination area, which is of necessity very restricted. Such dual entrances will be located off a common areaway located directly behind an exterior door. Depending on the structural capabilities of the entire structure, this door will be either a conventional exterior-type door or a specially

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designed blast-resistant door. No attempt will be made to seal this door against infiltration of contamination, since the areaway immediately behind the exterior door will become contaminated as soon as anyone enters it. Other structure entrances without decontamination facilities will be provided with airtight doors inside conventional or blast-proof exterior doors. Structure entrances and large openings with double doors will be kept to a minimum in order to restrict the exfiltration of air, resulting in the loss of interior pressure. Structures having depressed entrances where contamination can become trapped will be avoided or combined with the air exhaust system to provide for scavenging of such dead areas. The entryway may be developed as an appendage to a structure, either for future addition or for additions to existing structures that were not originally provided with CBR protection. (90) 9

The size of the decontamination cell will depend on the type of structure, the mission to be accomplished, and the number of persons who may utilize the facilities during any one period. Decontamination cells will not be provided for the passage of large groups of personnel, such as might be expected during a change in shift personnel during the continuous operation of a facility. (90) 12

Personnel subjected to contamination must enter a protective structure through an area having a continuous outward flow of air, space for undressing, means for disposing of contaminated clothing, facilities for showering, space for dressing, and clean clothing. (90) 13

Dressing rooms may be developed on a somewhat longer basis than that for undressing and showering, as air scavenging is not essential in this space. Floor areas of 12 square feet per person may be used as a basis for design. It may be advisable to combine the decontamination facilities with the toilet facilities of a structure, thus permitting the use of the toilet area as a dressing room. Under such circumstances provisions will be made for storing clothing and towels on shelves in the toilet areas. (90) 16

Air filtration, pressurization, and personnel decontamination are the three basic principles of CBR protection. (90) 2. Also to be considered are air circulation and removal of contaminants.

1. A small decontamination cell

The decontamination cell shown in the following figure is designed to process three personnel at a time. The following table shows area allocations for the cell.

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	Usable square meters/ person	Number personnel/ attendants	Usable square meters
1. Waiting room	0.60	6	3.6
2. Control area	3.6	1	1.6
3. Derober/liquid ingress	1.7	3/1	5.1
4. Shower	1.6	3	4.8
5. Dressing	1.2	3/1	3.6
6. Egress vapor	1.2	3	4.8
7. Egress liquid	1.7	3	5.1

The decontamination cell arrangement should be similar to the example shown. The rooms and their functions are as follows:

Waiting room (1)--Initial entry point and waiting area.

Control room (2)--Allows surveillance of processing personnel.

Derober/liquid ingress (3)--Serves as an area to clean and remove outer garments. Immediately upon entering door B, personnel walk through a box of powder, then on to metal grating to remove the powder. Next, an overhead shower over a metal grating allows washdown of outer suit. Finally, personnel with help of handler removes outer suit.

Shower (4)--Personnel shower to ensure that no final trace of contaminant remains. A window between rooms 2 and 4 allows surveillance of processing personnel.

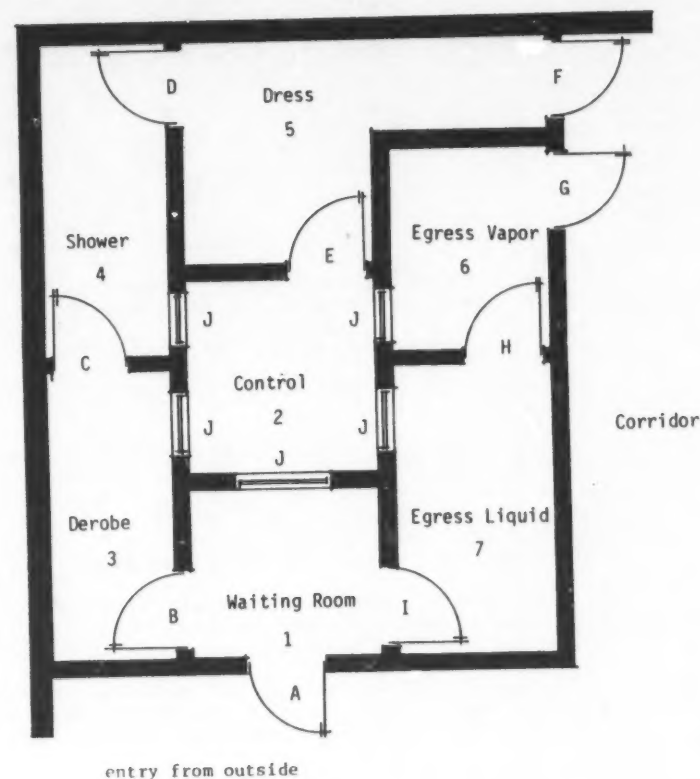
Dressing (5)--Final air lock and dressing area before entering interior of building. Window in door allows surveillance of processing personnel from building interior.

Airlock egress (6)--Processing personnel pick up vapor contaminated items left during inprocessing.

Airlock egress (7)--Processing personnel put on outer garments and pick up liquid contaminated items left during inprocessing.

Airflow in the decontamination cell should be controlled to ensure that no air can flow back into the interior of the facility or into the previous room. Control of backflow is accomplished through stepped pressure in each room (that is, with overpressure inside being the lowest at the entrance (discussed later below), stepped airflow into each room in sequence with the operation process, and minimum-size door openings. Air pressure regulators and anti-backdraft valves maintain the pressure difference between rooms.

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There should be an electromagnetic door lock on decontamination doors A, B, D, E, F, G, H, and I. The lock shall be provided with a timing device adjustable between 0 and 10 minutes. This feature is required to ensure that the air in the room is purged before the door is opened into the next room during decontamination processing. It is also required to ensure that no more than two interconnecting rooms are open to each other at a time.

Door A can be opened only when doors B and I are secure.
Door B or I can be opened only when door A is secured.

Door D can be opened only when door E is secured.

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Door C stays secured for 0 to 10 minutes after door B is closed.

Door D can be opened only when doors B and F are secured.

Door D stays secured for 0 to 10 minutes after door C and F are closed.

Door F can be opened only when doors E and D are secured.

Door F stays secured for 0 to 10 minutes after door D is closed.

Door G can be opened only when door H is secured.

Door I stays secured for 0 to 10 minutes after door H is closed.

Door H can be opened only when doors I and G are secured.

Door E can be opened only when doors F and D are secured.

The door interlock system is controlled from a main panel in the hallway on the clean side of doors G and H. The door interlock control system shall be designed to permit deactivation of any door lock or the entire system. Locks are to move to an unlocked position if electrical power fails. For day-to-day operations (the non-chemical warfare mode), the control system shall have all interlocks deactivated except doors B and I, which shall be controllable from remote switches at opening J. The door interlock system shall be waterproof to enable a complete washdown.

Gas door--Standard hollow metal door provides a gas-tight seal.

Gas/curtain door--Standard hollow metal door provides a gas-tight seal. Metal door. A nylon curtain with slit is attached to the door to keep the adjacent room from equalizing when door is opened.

Door A--Gas door with a minimum clearance of 1 meter.

Door B--Gas door with a minimum clearance of 1 meter.

Door I--Gas door with a minimum clearance of 1 meter.

Doors C, D, and E--Gas doors with a minimum clearance of 0.8 meter.

Door F--Gas/curtain door with a minimum clearance of 0.8 meter.

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Door H--Gas door with a minimum clearance of 1 meter.

Door G--Gas/curtain door with a minimum clearance of 1 meter.

Opening J--Solid safety glass window 0.6 meter wide for viewing only.

2. A large decontamination cell

Sites exposed to persistent CBR agents require a decontamination station for personnel entering the building. The typical decontamination facility shown can accommodate 60 people an hour. (89) A-6

In the decontamination cell shown, personnel enter the system through the 45-degree swinging door. All items of clothing except respirators are removed and deposited in the clothing chutes. Plastic bags should be provided for personal belongings other than clothing. These belongings should be identified and placed in the clothing chute. After undressing, personnel will proceed to a vacant shower head and bathe. This bathing procedure consists of entering the shower area, rinsing with clear water only, discarding the respirator through a clothing chute provided, continuing to shower using soap and water, and rinsing thoroughly. The minimum showering time is 3 minutes per person, but 4 or 5 minutes per person is more practical. (91) 43

The shower room should be equipped as follows: (89) A-7

At least one spray nozzle per shower station, located approximately 6 feet from the floor.

Three gallons of water per minute per shower station.

Temperature of 100°F.

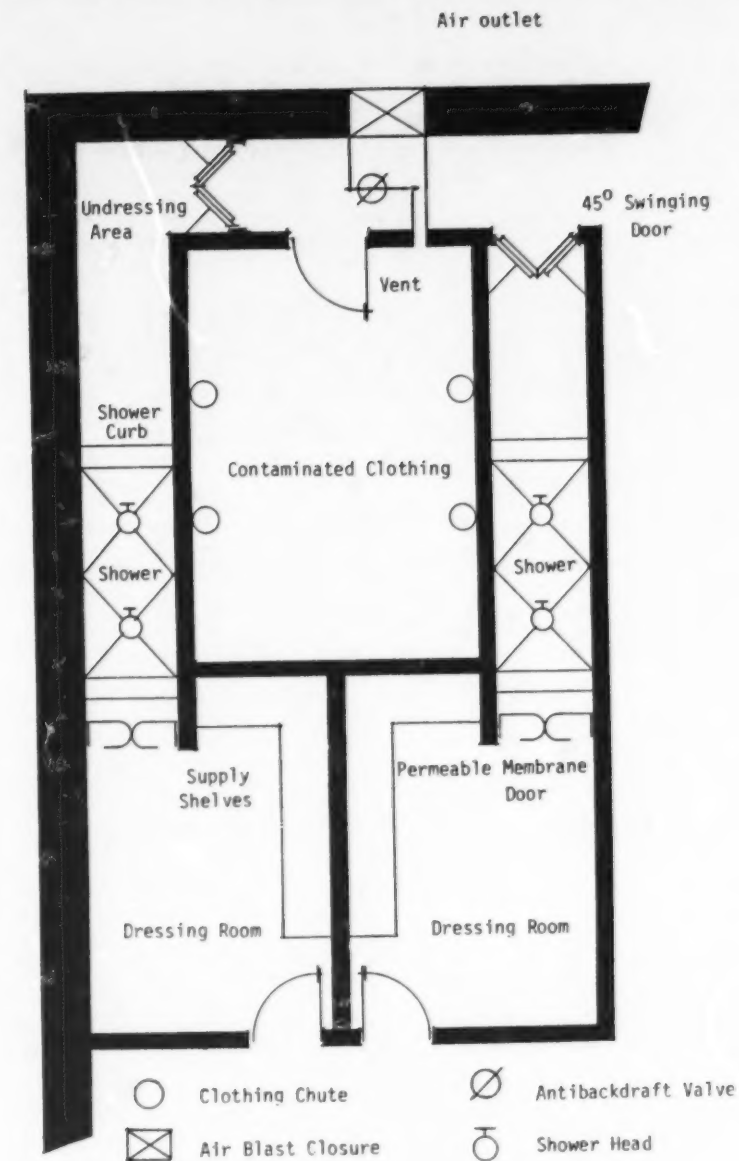
Nine square feet minimum floor area per person (3 feet by 3 feet).

Metal grating floor.

To prevent the spread of contamination in the showering area, the following precautions must be taken:

The showering facilities should be arranged so that persons already decontaminated are not recontaminated when leaving the shower room by those persons still showering.

Drainage water from this area should be directed to sanitary drains near the entrance or the center of the shower room.

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Drainage water should never be allowed to flow through occupied areas of the shelter.

Adequate traps and blast closures should protect the sanitary drain.

After showering, personnel enter the dressing room, where they dry and dress. Provisions must be made here for the issue of towels and clean clothing. A first-aid kit should be placed in this room to take care of minor injuries and emergency medical supplies for agent exposure treatment. The minimum floor space for occupant in the dressing room should be 12 square feet. (89) A-8

3. A portable collapsible decontamination cell

This facility is now being designed by the Chemical Systems Laboratory (CSL), Aberdeen Proving Ground, MD. The facility is fully equipped, including showers. It requires utilities, can be stored in a small or remote space, and erected in one hour by a crew of 14 men. It is designed to decontaminate 320 people per hour. For up-to-date information, contact CSL (Mr. George P. Smith, phone 301-671-2295).

b. Decontamination station construction materials and building items

1. Building materials (except for the portable collapsible type)

The walls and floor should have a ceramic tile finish. A 5-ply waterproofing should be installed in the decontamination cell floor. The ceiling should have a liquid-glaze coating.

The construction material should be reinforced concrete. It should include a slab ceiling 2.3 meters above the floor of rooms 4, 5, and 6 (see room layout of the small decontamination cell). Ladder access should be provided to the space above the ceiling for storage. This is a clean space. This lowered ceiling also lowers the volume of air that must be exchanged in the airlocks. Rooms 1, 2, 3, and 7 are full height.

Interior finish schedule:

Floor--Mosaic glazed floor tile

Base--Glazed wall tile

Wall--Glazed wall tile on concrete/concrete masonry unit

Ceiling--Concrete liquid-glazed coating.

2. Door hardware

Door hardware should be of rugged design and made of

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bronze or another noncorrosive material. Airtight doors will be provided with at least three 5- by 5-inch butt hinges and a wedge-type latching device. Doors between contaminated and uncontaminated areas will be provided with a locking device similar to a bolt-type latch to prevent inadvertent opening from the contaminated side. (90) 11

Airtight doors that will be used for normal entry and exit will be provided with seals that are readily adjustable and replaceable. Doors will swing in to the higher pressure area to ensure better sealing. (90) 10

In most cases, the only airtight doors are those opening to the outdoors or to areas of contamination. Mechanical closing of pedestrian doors is not recommended. Mechanical operation will be limited to doors of excessive size and weight, and mechanical controls will be located at the door. Remote audible and visual devices indicating position of doors may be placed on all doors if necessary. (90) 10

3. Seals

Sealing materials fall into the following categories: caulking compounds, non-hardening extruded tapes, non-hardening mastics, strippable spray coatings, pressure sensitive tapes, gaskets, adhesives, fabrics, films, and miscellaneous grommets, plates, inserts, self-sealing screws, and so forth.

Sealants that minimize air leakage and provide protection against chemical-biological (CB) agents must meet three primary requisites. They must be (1) impermeable to air, (2) resistant to CB agents, and (3) easily installed. Sealing materials must also be durable so they can withstand environmental extremes and field operation conditions. Materials must have shelf lives compatible with normal procurement and usage practices. Toxic, flammable, or explosive compounds must not be used. It is also desirable that the materials be covered by Federal specifications and available within the Army supply system. (167) 66

Sealants are similar in function to gaskets in that they are used to exclude dust, dirt, moisture, air and chemicals. The main distinction between a sealant and a gasket is that a sealant applied as a nonsolid while gaskets are usually performed to fit and are always placed between mating surfaces.

Seals of neoprene rubber or a similar elastic material are used in permanent-type structures. Such seals should be fitted in nonferrous metal strips fastened to the door frame in such a way that adjustment may be readily made with doors closed. Seals of nonferrous metal weather stripping may be used on doors that are not susceptible to possible

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infiltration of contamination if there is a pressure loss in the structure. Seals should never be placed on blast-resistant doors. (90) 11 For an update on new sealants, contact the Chemical Systems Laboratory, Aberdeen Proving Ground, MD (Mr. Lou D. Elicio, phone 301-671-2532).

4. Processing control intercom and lighting

An intercom system for control of personnel processing through the decontamination cell should be provided. Each room, including one outside of door A, should be equipped for transmitting and receiving. The master control should be located near the door interlock control panel. The complete intercom system should be waterproof to enable complete washdown.

A two-color (red and green) control light system should be provided to regulate processing through the decontamination cells. A set of lights should be located in each room next to the door jamb of the door used for exiting. The red light is to be switched at each room from closure of entering door, and the green light is to be switched at the master control panel by a timing relay. A master light controller should be part of the interlock control panel. Lights and wiring should be waterproof to enable a complete washdown.

C. Decontamination station systems**1. CBR filtering system**

A CBR filtering system consists of a commercial-type prefilter to remove coarse dust particles, a particulate filter to remove particulates and aerosols as small as 0.3 micron with 99.97 percent efficiency, and a charcoal filter where chemical agents are absorbed. Currently available particulate and gas filters developed by the Chemical Systems Laboratory (CSL) at Edgewood Arsenal will provide protection against all known CBR contaminants. However, they do not provide protection against carbon monoxide or ammonia. (89) A-1 Filter units are also available that incorporate a gas and particulate filter into one unit; these units have a blower and ducting. The blower can be driven by an electric motor or a gasoline engine. The unit is portable and skid mounted. It provides ventilation and creates overpressures.

Dual-filter banks are recommended. One bank is used while the other remains in stand-by condition. The charcoal needed by the gas filter will be replaced by the manufacturer in 5 to 10 years, depending on whether continuous or by-pass system design has been used. There are designs which permit makeup air to bypass the air purification system during emergency conditions. CSL does not recommend this practice because no filtering would be provided in case of covert or surprise attack. (89) A-2

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The effectiveness of a CBR filtering system diminishes gradually because of natural particle contamination. The system can be monitored by a routine check of negative pressure, differential pressure, and air flow through the filter by operating personnel who are primarily responsible for other functions at the site. Abnormal conditions are best signaled by an alarm which is triggered when a monitored parameter exceeds or falls below some predetermined set point (determined by the CBR filter manufacturer). A centralized instrument display system is preferred for this operation. However, sufficient local instrumentation at the point of interest should also be provided to facilitate maintenance and inspection and to check the central instrumentation. Safe and reliable operation of an HVAC system with CBR filtering protection requires instruments that monitor the critical operating parameters. At a minimum, the instrumentation should measure pressure drop across each individual bank of filters (not just a simple instrument to read pressure drop across the HVAC system) and total air flow through the filter system. Pressures in the communication equipment areas and differential pressures between surrounding areas need to be monitored. Completely redundant and independent instrumentation systems are required so failure of one cannot affect the other. The differential pressure sensors should be tied to motor-operated relief vents to ensure adequate regulated pressure in the communications building. (89) A-3

Agent monitors must immediately warn of hazardous situations. The Government-furnished M8 Agent Detector can detect all vapor GV and VX nerve gases. A hydrogen flame emission detector is commercially available. The commercial unit is more sensitive to vapor GV and VX nerve gas than is the M8 Agent Detector. The GV and VX agents detector/alarms continuously monitor the area between the two absorber banks of each CBR filter system. A remote sampling probe within the filter housing interior is connected to an external alarm. When the contamination level is above the sensitivity threshold of the detector, an audible/visual alarm is activated in the control room to warn of a breakthrough of the first absorber bank. An automatic damper then reroutes the air flow to the other bank of CBR filters and the contaminated filter can be replaced. (89) A-3 An overhead hoist or power handling equipment is essential to lift and replace filters.

The HVAC must be operated continuously to maintain positive pressure in the communications equipment area and the mechanical room. The minimum pressure level should be 0.3 inch water above atmospheric at the outer air lock. Pressure should drop a maximum of 0.1 inch water for each succeeding chamber, starting with the main shelter; the lowest pressure should be in the outer air lock. (90) 17 (91) 13, (168) 39. To reduce the amount of filtered air required, air leakage from the structure must be minimized. All possible leaks,

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such as piping penetrations, waveguide penetrations, trench penetrations, doors, ventilators, and grille penetrations, should be sealed or weather stripped. Cracks around floor joints, pipes, and conduit penetrations through the outside walls of the communications buildings must be tightly caulked with cement or bituminous mastic and covered with a heavy coating of varnish. Cracks also can be sealed by tape, plastic sprays, and cement washes. Windows may be removed and sealed with exterior construction that eliminates air leakage and provides protection from small-arms fire. (89) A-4. Major sources of leakage are windows and doors, surface intersections, electrical and plumbing inlets, and faults in continuous surfaces such as walls and ceilings.

The layout and construction of the communications building (must be such as to reduce air leakage). Buildings with suspended ceilings must be redesigned to provide an adequate ceiling to maintain the required pressure of 0.1 inch or water. One technique for minimizing air leakage through the ceiling is replacing the suspended ceiling with gypsum board. The cracks can be sealed by the technique described earlier. An air lock system at the entrance to each communications building will limit air leakage. (89) A-4

The existing technique of furnishing outside ventilation (unfiltered fresh air) to amplifier units and other communications/electronic equipment needs to be discontinued. The present technique for cooling this equipment, which generates significant amounts of heat, is to introduce unfiltered outside air. This practice should be discontinued and the equipment tied directly to the HVAC system with flexible ducts. (89) A-5

The design rate of fresh air flow for most DCS sites is excessive. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE) recommends a minimum of 5 cubic feet per minute of fresh air per person for common operation procedures. The fresh air intake (intake grille, duct, and damper) and air pressure relief portion of the HVAC system should be redesigned to handle the flow of fresh air required to support personnel and to obtain the necessary positive pressure within communications areas. The rate of air leakage for a building determines the amount of extra fresh air that is required to counter the air leakage effect. The rate of air leakage for each communications building should be determined. (89) A-5

2. Air supply/return system

Air-cooled condensers for refrigeration systems and radiators from emergency generators should be protected by blast valves and housing equivalent to that of the protected facility. Where blowers are required for supply and exhaust to overcome the resistance of blast valves, bypasses for the

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blast valves shall be provided for operation during no-risk times. Blowers will preferably be the two-stage axial type to provide backup.

Blast valves shall not be provided for emergency diesel generator exhaust unless analysis shows that the exhaust system will not withstand blast pressures.

Air locks in the decontamination system will normally serve as exhaust paths for makeup air. During times of risk all makeup is to be exhausted through air locks, not through the toilet exhausts. Scavenging systems (recirculation systems passing air-lock room air through CB filters) shall be considered for refiltering to provide makeup air to the decontamination cell only.

One hundred percent backup for water pressurization pump and water circulating pumps is required.

Fresh air intake fans will normally be single, two-stage axials. They should be designed for 120 percent of air resistance through blast valves, CB filters, particulate filters, and piping, plus building overpressure.

A manometer system shall be included to provide pressure readings at designated locations. Locations of monitors will be denoted in the facility plan.

An adjustable air volume damper should be provided to control pressurization and cubic feet per minute flow through the decontamination cell.

Blast valve protection - All openings for the CBR system and the normal environmental system are to be protected from air blast pressure by means of blast valves.

Outside air should enter the structure through an air intake blast closure if the shelter is designed to withstand blast pressures. The blast closure provides protection against momentary excessive pressures which could damage the filters. (91) 9

3. Plumbing system

Hose bibs should be provide in each room for decontaminating the cell. The temperature of water supplied to the hose bibs shall be automatically mixed to 60°C (adjustable to least $\pm 10^\circ\text{C}$).

There should be one shower in room 3 and three showers in room 4. Shower heads shall be 100 millimeters in size, with a flow rate of 0.64 liters per second. A control valve operated by a pull chain or lever or push button is to give a timed supply of water lasting 15 seconds each time the valve is

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opened. The temperature of water supplied to the shower shall be automatically mixed at 40°C (adjustable at least $\pm 10^\circ\text{C}$).

A threshold at each door should be provided to stop water from entering an adjacent room during washdown. Each room should have a floor drain. Each drain shall have a deep water trap and built-in screen. A solid screw cover shall be provided for each drain to completely seal off the drain. The floor drain shall be flush with the floor with the cover installed.

There should be a separate drainage system for waste from the decontamination cell and dirty mechanical room. It should have the following characteristics:

- o Drain into a concrete holding tank located below the floor in the dirty mechanical room.
- o Tank size equivalent to the emergency water tank.
- o A pipe and connection for pumping out tank contents.
- o Valved overflow capability to a dry well, which should be encased in concrete from the tank to approximately 6 meters beyond the exterior wall.

The waste line from the toilet areas is to have a shut-off valve located near the building exit. In addition, the architect-engineer should recommend how to protect on the building sewerlines from blast pressure (such as an expansion chamber within the building). The building waste line should be encased in concrete similar to the decontamination cell waste line.

Designers will provide utility connections (water, sewer, and so forth) to base systems for normal operations. These connections will include flexible features to allow for differential movements between facilities and surrounding soils. External water and sewer connections must have blast protection to prevent blast pressures from entering facilities. Designers will consider emergency water storage and sewage holding for a "button-up" period. Lines for such emergency systems must be protected from blast pressures and should be enclosed in structural envelopes.

Pressurization--The minimum water pressure required is 15 millimeters. Under no-risk conditions, the facility should operate at normal pressurization levels (approximately 3 millimeters water) to save energy. Pressurization during risk conditions shall be provided by a makeup air blower system which is sized for pressure drops through blast valves, CB filters, particulate filters, and so forth.

guidance CBR THREATS/2 Decontamination Station**4. Warning and detection system**

Various devices are available for determining the presence of chemical, biological, and radiological agents in an area and for the instantaneous detection of chemical warfare (CW) and radiological warfare (RW) agents. The instantaneous detection devices warn shelter occupants of the presence of CW and RW agents inside the shelter and in areas surrounding the shelter. They are also used to monitor incoming air and entering personnel to determine the extent and type of contamination and to detect the degree of RW contamination of protective filters so the filters can be replaced if necessary. Several detection devices are equipped with audible alarms. (91) 47. Protective clothing should also be available for any outside work during or after a CBR attack.

5. Testing all systems

After installation of all equipment required to protect the shelter against CBR agents, an initial inspection, testing, and adjustment of component equipment is required to ensure proper operation. Simulated CBR agent aerosols and gases should be used to evaluate the CBR protection afforded. (91) 52

6. Updating existing systems

When a current facility is to be updated with a CBR system, an engineer must determine the potential leakage of air from the structure when the shelter area or building is pressurized, as well as the way to minimize this leakage. The fan capacities necessary to pressurize the area must also be calculated, along with means to control the distribution of air and to maintain static pressures from the main enclosures to the entry systems. (91) 3

External CBR filter enclosures are required for most DCS sites because existing mechanical rooms do not have enough space to house the filter and related equipment. The enclosure must be designed to protect the CBR filter and associated equipment from small-arms fire. A few DCS sites have multiple computerized environmental units to control the heating, humidity, and air-conditioning requirements for the communications buildings. In this case, the existing fresh air intake vents and ducts (located on the roof) should be removed, and the resulting penetrations sealed, using construction similar to that of the existing roof. The CBR filter and associated equipment may be installed at a central location in the free space between the ceiling and roof. One intake opening with a weather-protective cover should be installed to supply fresh air; from that central location, fresh air can be distributed to the various environmental control units in the communications building. (89) A-5

guidance CBR THREATS/2 Decontamination Station

Each site with air conditioning (A/C) uses either outside condensing units or chillers for heat rejection from the cooling medium. With the critical environmental requirement (70°F to 20°F and 50 percent humidity plus 5 percent) for communications equipment, the units need to be protected from small-arms fire. A number of DCS sites use two different types of heating and cooling, such as hot water radiator heating and a d.c. coil air-conditioning system. It is difficult to maintain a balance for the internal environmental conditions of the communications areas. A packaged HVAC unit should be installed to provide the desired environmental conditions. Where there is no A/C, a packaged HVAC unit should be installed to maintain environmental control. (89) A-6

7. Disposition of contaminated or unserviceable filters

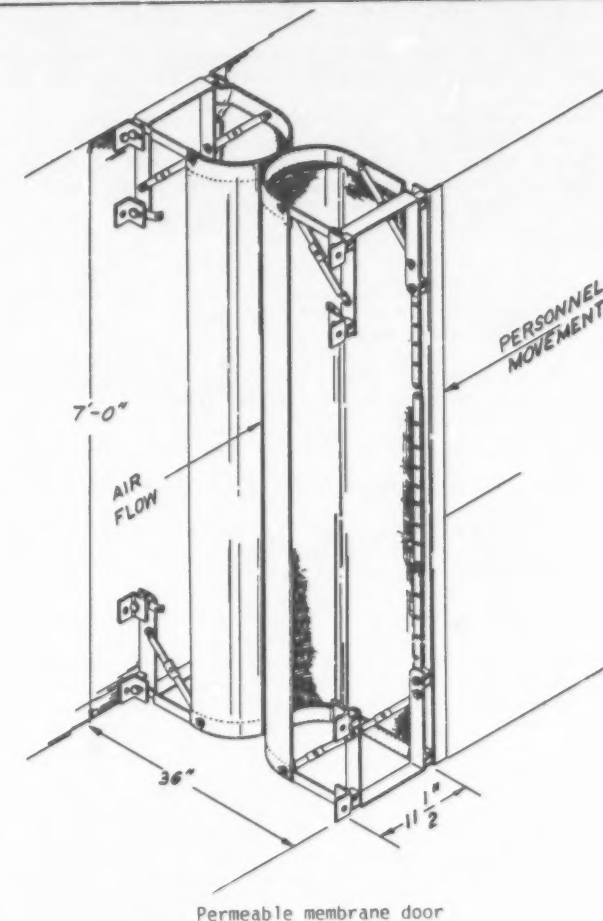
RW contaminated filters

Remove filter from base and wrap with flammable plastic sheet or paper and bury.

Safety precautions

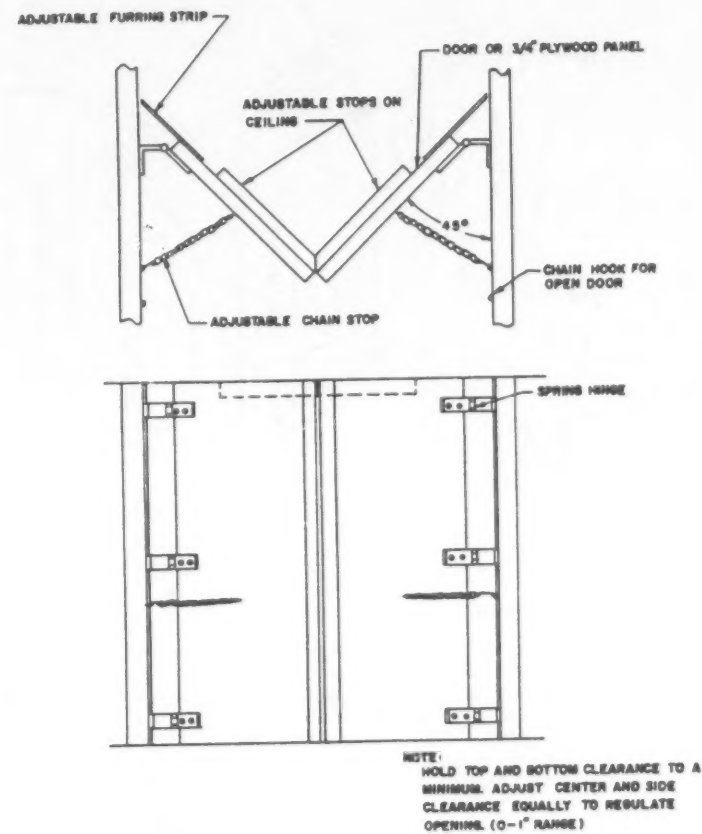
The heat of combustion will destroy BW agents, will partially destroy CW agents, but will not destroy the radioactivity of RW agents. Burn the filters when there is no wind or the wind is in a direction away from populated areas. Personnel must wear protective clothing and respirators when handling CBR-contaminated filters. See (91) 56-57 for more details:

guidance CBR THREATS/2 Decontamination Station



A permeable membrane door is used between the dressing area of the decontamination system and the shower room. The door is designed for installation in a corridor or doorway 3 feet wide and 7 feet high. The depth of the door is 11 1/2 inches. The door consists essentially of two lengths of one-way-stretch elastic webbing on metal frames. The webbing is permeable and permits a discharge of the filtered air supply evenly over its entire area. Two curving sections of fabric which meet to form a closure can be separated sufficiently enough to permit passage of personnel. The door can be folded against the wall when not in use. (91) 74

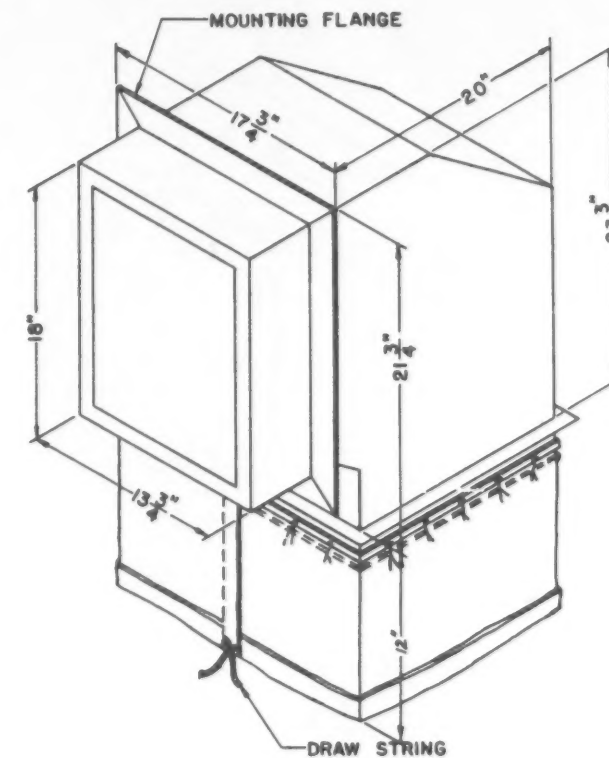
guidance CBR THREATS/2 Decontamination Station



Forty-five degree swinging access door

The 45° swinging door in this design is used to facilitate a uniform flow of air through the shower and undressing corridor as well as to maintain the required static pressure. Both air distribution and static pressure are controlled by adjusting the center opening and adjustable side furring strips when the door is closed. (91) 43

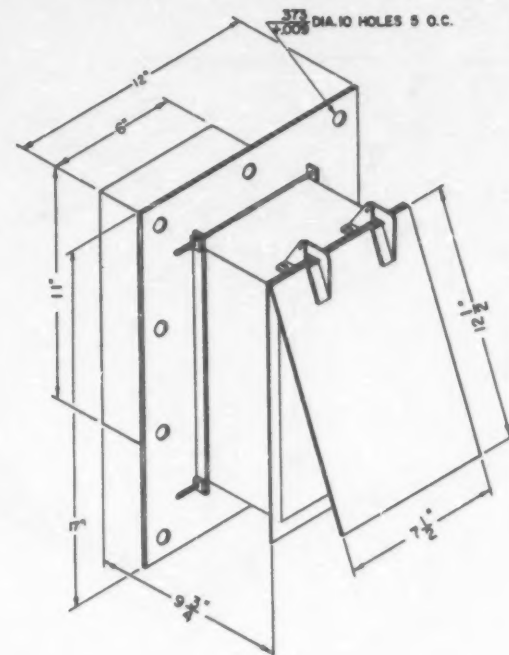
guidance CBR THREATS/2 Decontamination Station



Contaminated clothing chute

The contaminated clothing chute is used to move contaminated clothing from the air lock of a pressurized protective shelter to a contaminated clothing room or an outside area. The chute consists of a flanged front housing, which is fastened to a ductlike body. The receptacle used with the chute may be either a garbage can or a plastic bag. If a garbage can is used, the transition piece of a chute is fastened around the top of the can with a string. If a plastic bag is used, it is fastened to the chute body under the transition piece. The overall dimensions are 25- by 17-3/4 by 25-3/4 inches. (91) 74

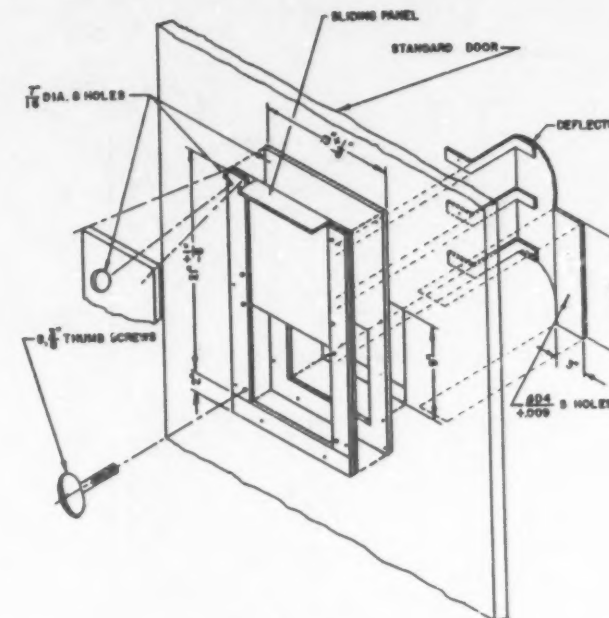
guidance CBR THREATS/2 Decontamination Station



Antibradraft valve

An antibradraft valve regulates positive pressure within ventilated (pressurized) protective shelters. The valve consists of a sheet-steel body fitted with a valve cover which is hinged at the top to open outward. It has three functions. First, the valve can be adjusted to maintain a predetermined static pressure of nearly constant valve within a pressurized shelter. Second, it prevents reverse flow of air from the atmosphere into the shelter if an outside pressure wave develops. Finally, the valve provides a way to determine the rate at which air is exhausted from the shelter to the atmosphere. During pressurization of the shelter, with air exhausting through the valve, the valve is adjusted to obtain the desired static pressure (pressure change across the valve). The valve cover closes automatically when the pressurizing system is turned off. The overall dimensions of the unit are 17 by 12 by 10 inches. Additional information can be found in TM 3-4240-203, "Accessory Equipment for Protective Shelters," November 1978. (91) 70

guidance CBR THREATS/2 Decontamination Station



Air pressure regulator

An air pressure regulator controls the air flow between sections of an air lock or between any other section of the shelter when air flow regulation is required. It consists of a steel panel which slides in a channeled frame. The lower portion of the frame has an opening 9 inches square. The height and width dimensions of the regulator are 23 and 13 inches, respectively. The panel may be raised or lowered in the channels to provide an air orifice varying in size up to the dimensions of the opening. Thumbscrews are provided to hold the panel in place when it has been adjusted to provide the desired pressure differential between sections of the shelter. One component, the deflector, produces a diffused and turbulent air flow through an air lock to achieve effective scavenging of airborne contaminants. The deflector is constructed of sheet metal, flat along one side for fastening to the wall, with a curved section extending from the flat side. Three supports which are welded to the perpendicular edge of the curved section are bolted to the shelter wall to provide rigidity. The overall dimensions of the deflector are 11 by 17 by 5 inches. Detailed instructions on installation, operation, and maintenance are given in TM 3-4240-203. (91) 74

9-1

DCA CIRCULAR 300-95-1

**SB9
Climate Conditions**



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SB9 CLIMATE CONDITIONS

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CLIMATE CONDITIONS

function

The location of a facility or installation within a site should be determined by analyzing the constraints and features of the area. This analysis should include the climatic constraints imposed by solar radiation, temperature, precipitation, and prevailing winds, as well as the natural features of the ground surface, such as topography, ground cover, and drainage patterns. (5E) 11

policy / s o p

To design a stable energy-efficient structure, the architect or planner needs a good description of soil conditions and climate. The soil conditions are a function not only of terrain but also of climate, which affects water drainage through the soil, by erosion, and by frost conditions (including permafrost). The principal climatic indicators from a biologist's standpoint are temperature and rainfall, since they affect the amount and types of vegetation. However, the architect needs to know how these climatic conditions compare with the environmental requirements of the equipment and personnel, and how they will load the structure that meets those requirements.

To do this, the primary climatic data must be converted into water runoff, snow loads, and the number of heating and cooling degree days. In addition to the basic climatic data, however, it is necessary to know wind speed and direction to calculate infiltration heat loss, possible utilization of wind energy, and wind loading on structural surfaces. The sun as a possible source of heat, light, or electrical energy must be investigated, as must the shielding effects of surrounding vegetation and structures.

These data can be gathered and used fairly easily for a single project on a given site. But for a design that is to be implemented worldwide the information must be broken down and classified by general trends, which can then be examined systematically to determine driving design factors. If a matrix of possible temperatures (frigid, temperate, tropical), rainfalls (arid, moist, wet), terrains (coastal, continental, mountainous), and prevailing winds (west or east) were prepared, the resulting four-dimensional matrix would contain 54 possible climates, most of which could not occur naturally.

Instead, four of the five general types of climates that do occur naturally, based on criteria of vegetative types, will be examined in terms of their impact on building foundation, structure, and climate control for DCS facilities design. The five general climates are polar, north temperate, south temperate, dry arid, and tropical-rainy. The polar climate will not be considered under this study. (7) C-1

issues and assumptions

1. Selection of materials

Two basic factors, availability and performance, have to be considered when materials are selected for buildings in any climate. The extent and rate of deterioration of building materials is caused in part by design, workmanship, and use. However, environmental factors are a major influence and have a profound effect on the durability and behavior of materials and structures. Materials which last well in hot, dry conditions may simply not be suitable in warm, humid areas. Moisture, temperature, ultraviolet radiation, and salt-laden winds all can have a detrimental effect on materials; two or more of these elements acting together almost invariably produce greater deterioration than if they were acting independently. Not only must the materials used be suitable for the specific climate conditions involved, but the design and detailing must be appropriate to both the materials and the climatic conditions. (67) 89

2. Structural frame construction

Provision should be made for the structural movement which is caused by intense solar radiation and large diurnal variations. In the hot-dry zones there can be a marked drop in temperature within a few hours once the sun sets, while in the humid areas temperature can be reduced very quickly by a heavy downpour. The stresses resulting from these continued rapid changes can cause bad cracks to develop. Sliding joints (for instance, between brick load-bearing walls and concrete slabs) and expansion joints in reinforced concrete structures must be carefully planned and detailed. Fibrous materials, together with suitable sealants, can be used to fill expansion joints. (67) 96

3. Soil diversity

The soil and groundwater should be tested. Although the soils found in the hot climate areas are similar to those in the temperate zone, there are differences. This is particularly true in the hot desert environments, where absence of rainwater and high evaporation rates lead to the precipitation of salts within the soils, necessitating the use of sulfate-resisting cements and the isolation of concrete from the soil by waterproof membranes. Measures to protect metal elements exposed to corrosive soils also will often be necessary. (67) 88

4. Microclimates

Even though the descriptions that follow help to classify climatic data into several well-defined groups, many factors can affect the behavior of a given climate at a given locale, resulting in a variety of microclimates within each of the five major climates. However, because these differences are only variations on a theme, knowledge of microclimates is used in site selection, small changes in orientation, and selection of package subsystems. The factors affecting microclimate are relationship to large bodies of water, terrain and topography, vegetation, and urbanization.

issues and assumptions

a. Relationship to water

The specific heat of land is less than that of water. Therefore, as the amount of incoming solar radiation varies daily and seasonally, the temperature over land changes more than over water. Large bodies of water can moderate the climate of surrounding land areas, reducing daily and seasonal temperature changes to as much as one-half the change at inland areas. Because of the temperature differences between land and water, coastline areas experience sea breezes and land breezes. During the day, when the air is warmer over land than water, a convection current in the air creates a breeze from the water toward the land, called the sea breeze. This, and the reverse land breeze at night, exist as a counterpoint to the prevailing winds. Also, coastal regions are more exposed to hurricane force winds. Major oceans are always in motion; their convective currents transport heat from equatorial oceans to arctic regions. Northern and western Europe have a temperate climate at latitudes much further north than the rest of the world, because heat from the Caribbean is carried north by the Gulf Stream. The interaction of warm water and cool air is the cause not only of the heavy fogs and rain in coastal areas, but also the long-term temperature inversions that stagnate the weather and trap pollutants. Finally, lands at latitudes common to desert climates may have tropical climates if they are near to, or surrounded by, water that can evaporate and provide rainfall.

b. Terrain and topography

Mountainous areas cause deviations from the overall climate. Dense cool air settles in the valleys at night, creating fog and frost conditions and a downslope evening breeze. However, valleys are warmer than the peaks during the day, so in the morning a breeze runs up the slopes. High elevations are naturally cooler than lower ones and experience a wider range of temperatures.

Windward sides of mountain ranges have more rainfall than leeward sides. The moist air carried by the prevailing wind cools as it rises to cross the range, so that the moisture condenses and precipitates before the winds can carry it over the mountains. Not only does this create a rain shadow on the leeward side, but as the now-dry air is adiabatically pressurized from a decrease in elevation, the resulting Chinook wind (common in the northern midwest) can cause temperature increases of 40° and 50°F in a few minutes.

c. Vegetation

Because of its shape and photosynthetic life process, vegetation modifies the microclimate in several ways. The trunks, branches, and leaves of trees drag on moving air, reducing wind speed at ground level. Trees can also channel breezes through or around buildings, providing desirable cooling during overheated periods or shielding from winter winds. Plant life not only acts

issues and assumptions

to filter particulate matter from the air, but its metabolic biochemistry reduces the carbon dioxide content of the air and increases the humidity. This process also absorbs solar energy, storing it as molecular energy so that the plants are shading devices that are not hot. Most important, deciduous trees lose their leaves in winter, allowing the sun to penetrate when it is needed.

d. Urbanization

Finally, the totally artificial environment of large cities exaggerates climatic behavior. The air temperature in metropolitan areas is generally a few degrees higher than in surrounding areas, because heat from building heat loss and industrial processes warms the air. This warm air rises, reducing the air pressure in the city. This pulls storms off course towards the city, making the weather worse than average there. While reflective surfaces of glass, concrete, brick, stone, and steel add heat to the air, the tall buildings shade the ground so that in winter street-level temperatures are colder than average. Buildings may act as wind shields and stagnate still air at ground level, but the long streets can be wind tunnels when the wind blows parallel to them. Adding to these problems, the nonpermeable surfaces in urban areas prevent the natural seepage of water into the soil, requiring storm sewers to be constructed so that rainfall does not flood the streets.

5. Design subsystems

The problem with generalized designs, even though they have reduced the design load from hundreds of specialized designs, is that they are perfect for the general case, but are gradually less useful as conditions vary daily and geographically from the norm. At the same time, some design factors are the same in the different climates. Hence, rather than designing five complete facility types, one for each climate, interchangeable subsystems should be designed according to the driving factors described above. Then, subsystems themselves, and their combinations, can be "fine-tuned" to the daily, seasonal, and geographical variations of the climate and microclimate. Also, some of the subsystems may apply to more than one class (permanent, semipermanent, and temporary) of DCS facility type. (7) C-11

6. Site analysis

Knowledge of the site elements can be used not only to take advantage of existing site elements but also to improve the site's microclimate. At the preliminary schematic design phase, three general questions about a site's climatic conditions are pertinent. (170) 51

- Is the site too warm or too cold?
- Too windy or not windy enough?
- Too humid or too dry?

Issues and assumptions**a. Manipulation of elements**

Some basic rules of thumb for manipulating site elements are as follows.

If the site is too warm:

- Use extensive turf and ground cover on the site.
- Use extensive coarse-textured, deciduous or coniferous shade trees and vines, especially on the south side.
- Plant to divert breezes to the building.
- Use trellises, arbors, and canopies.
- Remove windbreaks.
- Locate buildings on leeward side of water.
- Provide fountains, pools, and so forth.
- Use raised decks for pavings.

If the site is too cool:

- Locate to windward side of water.
- Maximize solar radiation by removing shade trees.
- Increase paved areas.
- Use fences and screens as windbreaks to deflect cold winds.
- Use light, lacy deciduous trees for shade.
- Use vegetational canopies to reduce night heat loss.
- Avoid pools and fountains on site.

If the site is too windy:

- Screen to divert winds.
- Avoid valleys and hillside slopes.
- Depress outdoor areas below ground level if possible.
- Use heavy coniferous windbreaks.

If the site is not windy enough:

- Remove undergrowth.

Issues and assumptions

- Locate on a hilltop or narrow valley slope.

- Create diverts with vegetation, earth forms, or built forms.

If the site is too humid:

- Maximize solar exposure.
- Maximize air flow.
- Pave ground surfaces.
- Locate high on the site and provide an extensive drainage system.
- Reduce vegetation, including canopy trees.
- Use vegetation with needle-like leaves to capture fog before it reaches the building.

If the site is too dry:

- Provide low windbreaks.
- Use irrigated turf or ground cover.
- Avoid large expanses of paving.
- Encourage overhead planting.

b. First step

The first step in site analysis or retrofit design involves recording: (170) 51

- Amount of solar radiation on the site.
- Time of day the sun hits the site.
- Impediments blocking the sun.
- Prevailing wind patterns.
- Impediments to wind movement.
- Areas where snow piles up.
- Damp or moist areas.

issues and assumptions

WORLD CLIMATE QUANTITIES

(7) II-13

	Polar	Temperature	Hot-Arid	Tropical
Daylight hrs winter	0 - 4	4 - 10	10 - 11	11 - 12
Daylight hrs summer	20 - 24	14 - 20	13 - 14	12 - 13
Temp avg winter	< 15°F	20°F - 45°F	40°F - 70°F	70°F - 80°F
Temp avg summer	40°F - 60°F	60°F - 88°F	80°F - 100°F	70°F - 80°F
Extreme hot	90°F	100°F - 110°F	125°F	105°F
Extreme cold	-120°F	-50°F - 10°F	-15°F - 20°F	35°F
Freezing	Always	Intermittent	Occasional	None
Frostline depth	Permafrost	3' - 8"	< 2'	None
Heating degree days	711,000	2 - 11,000	0 - 5000	None
Cooling degree days	None	0 - 3000	1000 - 6000	> 3,000
% sunshine	30 - 50%	40 - 60%	70% - 90%+	50 - 80%
Precipitation	0 - 20"	20 - 50"	0 - 20"	40 - 100"
Snow cover	Always	Intermittent to 8"	Intermittent up to 4"	None
Meridian solar altitude winter	-23½° - 6½°	6½° - 43°	30° - 52°	43° - 66½°
Meridian solar altitude summer	23½° - 53½°	53½° - 90°	77° - 99°	90° - 113½°
Max solar azimuth winter	None - 37°	37° - 64°	60° - 66°	64° - 66½°
Max solar azimuth summer	All the way - 143°	143° - 166°	120° - 114°	116° - 113½°
Wind direction	NE	W	EW	NE

issues and assumptions

c. Retrofitting for energy conservation

The existing site can be modified by adding, subtracting, thinning or moving objects on the site. Some things easily done to retrofit for energy conservation include:

- Remove, thin, or replace large deciduous trees on the south side to permit solar collection.
- Create outdoor sun pockets on the south or southwest.
- Provide solid wind screens to block winter winds.
- Replace turf with paving for a heat sink, if the site is too cold.
- Regrade earth to form berms around the building.
- Use louvered fence panels to allow for summer ventilation while deflecting cold winter winds.

d. Effects of altitude

Generally speaking, the designer should expect more cloudiness and precipitation, deeper snow pack, higher winds, more frequent icing conditions, and lower temperatures on mountain sites than on nearby lowlands, where weather records are most likely to be available. The temperature decrease with altitude may be as much as 10°C per kilometer. Temperature and humidity contrasts in coastal areas, in conjunction with local wind circulations, favor extreme refractivity gradients that can cause propagation anomalies. (2) 4-48

e. Radio sites

Weather conditions are an important factor in the construction, support, and operation of radio sites. Unless the designer is already very familiar with climatic conditions in the area of the proposed radio links, he should obtain information from a source such as the Air Weather Service, Air Force Environmental Technical Application Center (ETAC), or the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). Publications such as the "World Survey of Climatology" and "Climate of the Continents" are useful sources of information, as are data summaries such as the ETAC "Worldwide Airfield Climatic Data" and the British Meteorological Office "Tables of Temperature, Relative Humidity and Precipitation for the World." (2) 4-47

requirements	criteria	commentary
NORTH TEMPERATE 1. Energy conservation	1. Energy conservation The building and site design should maximize energy conservation with regard to the mission of the facility. a. Climatic considerations b. Conservation measures	
2. Building layout	2. Building layout A site's climate must be analyzed to determine the appropriate interrelationship of site elements. a. Site selection b. Site structure c. Public spaces d. Landscape e. Vegetation f. General arrangement g. Form, volume h. Orientation	

requirements	criteria	commentary
3. Building elements	3. Building elements Each climate dictates the proper components and construction practices that should be used for the buildings. a. Openings and windows b. Walls c. Roof d. Materials e. Mechanical equipment f. Foundation	

requirements	criteria	commentary
SOUTH TEMPERATE 1. Energy conservation	1. Energy conservation The building and site design should maximize energy conservation with regard to the mission of the facility. a. Climate considerations b. Conservation measures	
2. Building layout	2. Building layout A site's climate must be analyzed to determine the appropriate interrelationship of site elements. a. Site selection b. Site structures c. Public spaces d. Landscape e. Vegetation f. General arrangement g. Plan h. Form, volume i. Orientation j. Interior	

requirements	criteria	commentary
3. Building elements	3. Building elements Each climate dictates the proper components and construction practices that should be used for the buildings. a. Opening and windows b. Walls c. Roof d. Materials	

requirements	criteria	commentary
HOT ARID 1. Energy conservation	1. Energy conservation The building and site design should maximize energy conservation with regard to the mission of the facility. a. Climate considerations b. Conservation measures	
2. Building layout	2. Building layout A site's climate must be analyzed to determine the appropriate interrelationship of site elements. a. Site selection b. Site structure c. Public spaces d. Landscape e. Vegetation f. General arrangements g. Plan h. Form, volume i. Orientation j. Interior	

requirements	criteria	commentary
3. Building elements	3. Building elements Each climate dictates the proper components and construction practices that should be used for the buildings. a. Openings and windows b. Walls c. Roof d. Materials e. Shading devices f. Mechanical equipment g. Foundation	
4. Soil-related problems	4. Soil-related problems Hot arid climates can degrade the performance of the facility.	

requirements	criteria	commentary
HOT HUMID 1. Energy conservation	1. Energy conservation The building and site design should maximize energy conservation with regard to the mission of the facility. a. Climate considerations b. Conservation measures	
2. Building layout	2. Building layout A site's climate must be analyzed to determine the appropriate interrelationship of site elements. a. Site selection b. Site structure c. Public spaces d. Landscape e. Vegetation f. General arrangement g. Plan h. Form, volume i. Orientation j. Interior	

requirements	criteria	commentary
3. Building elements	3. Building elements Each climate dictates the proper components and construction practices that should be used for the buildings. a. Openings and windows b. Walls c. Roof d. Materials e. Shading devices f. Mechanical equipment	

guidance NORTH TEMPERATE/1 Energy Conservation**1. a. Climate considerations (7) C-3**

Long, cold winters with abundant snowfall and short summers are the dominant characteristics of this climatic region. The snow forest of tall coniferous trees and limited underbrush indicates the difficulties of biological survival. The short winter days, with as few as six hours of sunlight, combined with average winter sun angles less than 30° off the horizon, can cause temperatures below zero for several weeks at a time and keep average daily highs below freezing during December, January, and February.

Although it may not accumulate continually, snow cover is continuous throughout the winter months, and patches may remain well into the summer. Average snowfall may exceed 60 inches in a single season, with 30 inches falling in a single month. A single storm may precipitate 6 to 12 inches of snow in a 24-hour period with drifts averaging 6 feet at the crest.

Snow loads above 60 pounds per square foot are possible; recent collapses of large clear-span structures have led to investigation into the effects of snow loading.

Although there is no permafrost, the line of frost action from the surface down may be as much as 8 feet. Groundwater in the aerated portion of the soil freezes and expands the soil, causing any structures with footing on the frozen soil to lift or heave. These expanded areas are more susceptible to erosion during the spring runoff, which can bring the water table all the way up to the soil surface. These expanded areas are the major cause of potholes in road surfaces. Because of the excavation depth required to place footings below the frostline, typical foundations are full basements adequately sealed with tar, pitch, or plastic film against water from the spring runoff.

Because of the length and severity of the cold season there are more than 7000 heating degree days per year; more than 10,000 are possible. Active collection of solar energy as a primary source of hot water or electricity is not feasible on a year-round basis because of the short winter days and cloud cover, but techniques that take advantage of the sun to reduce the heating load without adding to building cost should be used as much as possible. Besides south-facing glass, reflective surfaces (to throw additional sun on the glass), and radiant thermal mass, earth sheltering or berming techniques have proven successful as inexpensive thermal insulation, wind deflectors, and a conductive connection to the thermal mass of the earth itself. These techniques are advantageous in both summer and winter. Airtight construction with 6 to 12 inches of insulation is necessary. Wherever possible, direct sunlight should be used to increase the level of ambient light.

The softwood forest can reduce wind speed at ground level significantly, but above the tree tops there is enough wind energy

guidance NORTH TEMPERATE/2 Building Layout

for useful collection and conversion. In summer, adequate cooling can usually be achieved with the available breezes if landscaping and openings are oriented to allow ventilation through the building from the prevailing west-northwesterly direction.

b. Conservation measures (171) 16

Design and site buildings primarily for winter heat conservation by maximizing the warming effect of solar radiation in water and reducing the impact of cold winter winds.

- Utilize south- and southeast-facing slopes.
- Orient active outdoor pedestrian areas of the building to the south.
- Create protected sun pockets for outdoor pedestrian areas.
- Utilize medium-colored building surfaces exposed to the sun and dark colors on recessed surfaces to absorb solar radiation.
- Use generous south-facing windows to capture warming solar radiation within the building interior.
- Locate buildings on the leeward side of hills in the "wind shadow."
- Use the natural insulation of the earth where possible--for example, build into hillsides to reduce winter heat loss.
- Use evergreens, earth berms or mounds, and walls to provide winter wind screening of north-facing building walls.
- Minimize unshielded window areas on exposed north-facing walls that face prevailing winter winds.
- Minimize the extent of a building's exterior surface area by consolidating buildings or building masses into a compact configuration.

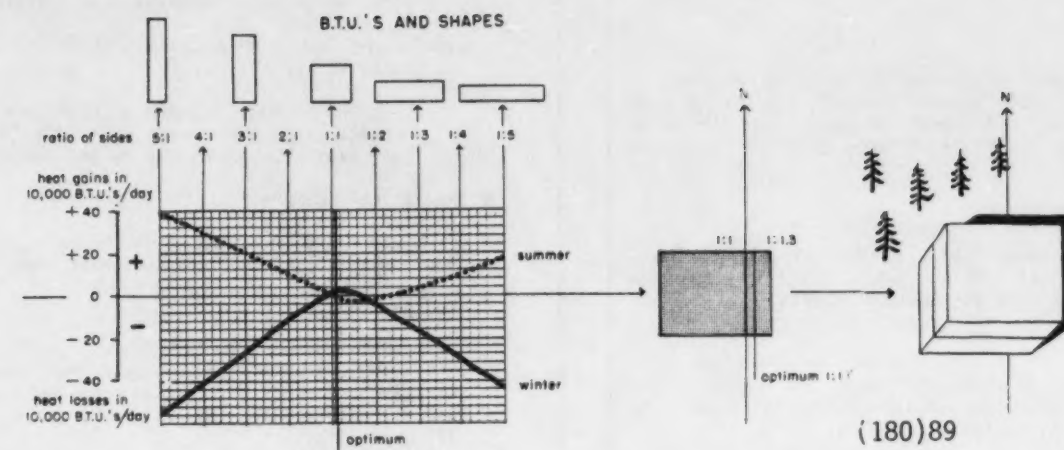
2. Building layout (180) 155-6**a. Site selection**

A south-southeast slope for sun gain is desirable. The middle or lower middle part of slope is preferable to prevent excessive wind effects and to avoid cool air pools.

b. Site structure

The layout shall provide shelter against winds. Larger building units may be grouped close together but spaced to utilize sun heat effects. If the buildings tend to join, less surface will be exposed to heat loss. The site structure is an inclined dense layout. (See "Security Systems.")

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Public spaces should be sheltered from the wind and open, with periodically shaded areas.

Landscape

The generally varying topography shapes street layouts and space utilization into an irregular character.

d. Vegetation

Evergreen windbreaks in the northeast-southwest direction at a distance of 20 times the tree height are desirable. Deciduous shade trees should be placed near buildings. Avoid dense planting too close to structure because of the effect of dampness. (See "Security Systems.")

e. General arrangements

Conservation and economy of heating are about three times as important as provisions for summer comfort. The extreme conditions in both winter and summer suggest that there be separated zones for these two roles. Avoid exterior steps and steep drives.

f. Form, volume

Structures should be compact with minimum exterior surface. Volume effect is highly desirable. A1: 1.1-1.3 proportion elongated on an east-west axis gives optimum effects.

g. Orientation

Optimum sun orientation lies 12° east of south. The prevailing wind pattern (northwest-southeast) may influence the orientation of free-standing buildings.

3. Building elements (180) 156**a. Openings and windows**

Sun windows will provide good auxiliary heat sources. The windows should be small except on the south side and part of the east side. Windows should be protected by shade during times of overheating. Heavy draperies or shutters are desirable to reduce heat loss during cool periods. Double glazing is essential. Controlled ventilation is a primary requirement (maximum 20 feet per minute air movement). At overhead times, cross ventilation is desirable.

b. Walls

Exterior surfaces of smooth nonabsorbent materials are preferable. Insulation should be at low thermal capacity.

guidance SOUTH TEMPERATE/1 Energy Conservation**c. Roof**

A sloping roof will encourage snow removal by the wind. Flat roofs without parapet walls clear themselves more rapidly. A simple roof formation is desirable to prevent moisture penetration and ice-filled gutters.

d. Materials

1. Low thermal capacity insulation should be designed to resist a winter thermal gradient of 88°F. The required insulation values relative to south are: east-1.2; west-1.2; north-1.3; roof-1.4.
2. High heat capacity mass in the interior to balance extreme heat variations is desirable; west wall material with a 3-hour time lag balances internal heat distribution.
3. There should be a vapor seal on the warm (interior) side of outer walls.
4. Avoid exterior materials that are absorbent and subject ranges, it is necessary to avoid materials subject to stress from expansion, contraction, and excessive dryness.

e. Mechanical equipment

Water and sewer pipes should be kept out of exterior walls, particularly northwest and southeast ones.

f. Foundation

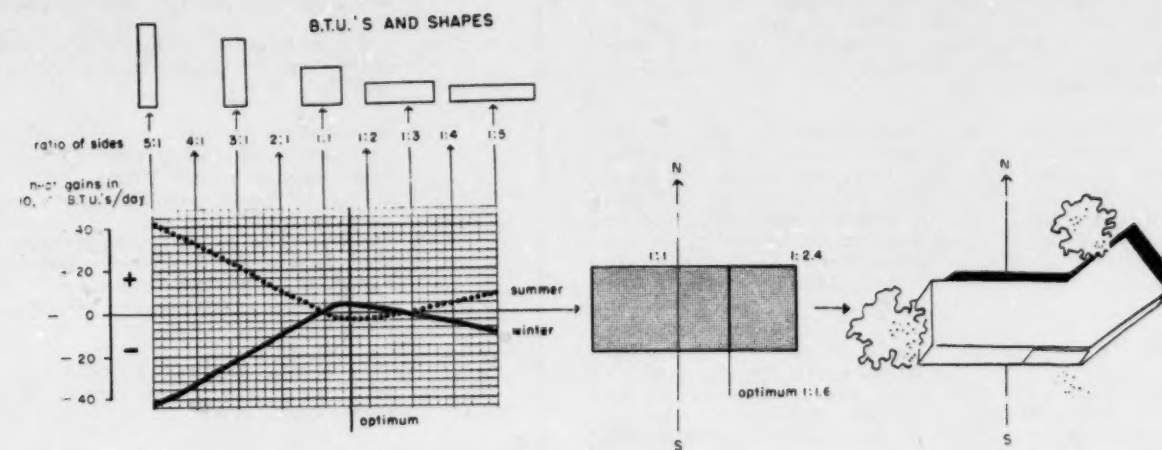
While there is no permafrost, the line of frost action from the surface can be as much as 8 feet down. Groundwater in the aerated portion of the soil freezes and expands the soil, causing any structures with footing on the frozen soil to lift or heave. (7) C-4

1. a. Climate considerations (7) C-5

Temperate and cool climates are differentiated by the type of winter they have. In the south temperate region, snow falls but does not accumulate--the temperature rarely stays below freezing for more than a week. Often a snowfall will melt away completely before the next arrives. During the winter there are as many inches of rainfall as snowfall, and precipitation is more likely to take the form of ice or sleet storms because of the marginal conditions for snow.

In general, the temperature goes below freezing at night and warms to above freezing during the day. In the portions of the region closest to tropical climates, there may be only two or three periods of nighttime freezing in an entire winter season, and continuous freezing for more than 24 hours is rare. The frostline extends no more than 4 feet below the ground surface.

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(180)89

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It is usually less than 2 feet, making unexcavated foundations (such as a flat or turned-under slab, raft, or stem wall) sufficient.

Active solar collection for primary hot water or electricity is not recommended because the sky is cloudy, with less than 50 percent of the potential sunlight available. However, there is enough sunshine that the energy efficiency of a building shape is not entirely a function of surface-to-volume ratios. Because the low-altitude winter sun can warm the south side of a building, and the rising and setting summer sun warms the east and west sides too much, the optimum building shape is a rectangle with a length-to-width ratio of 1.6:1 and with the long axis running in an east-west direction. Using earth sheltering techniques to protect the north, east, and west sides, this length-to-width ratio can be increased to gain more winter sun. Increasing the ratio also helps protect against windstorms, tornadoes, and hurricanes, which are common in this climatic region.

There are 2000 to 7000 heating degree days per year in the south temperate region, making a permanent and reliable heating system necessary. Passive solar techniques can reduce the total seasonal fuel consumption, but heating systems must be designed for the extreme conditions: 0°F, 35 mile per hour wind, and no sunlight. There should be at least 3 inches of insulation in the walls and 6 inches in the ceiling. Insulation in the north, east, and west walls should be 1.3 to 1.4 times thicker than in the south wall.

Summers can be uncomfortable, with between 500 and 3000 cooling degree days, daily high temperatures in the 80s and 90s (going into the 100s during a heat wave), and relative humidities over 80 percent. When temperatures are over 70°F it is essential to shade any areas used in the direct collection of sunlight for heat--windows, south-facing walls, reflective patios, and so forth. Because the sun shines from different angles in the winter and summer months, fixed devices can be designed to shade the sun only in summer. However, movable devices allow for minor changes in the microclimate. Deciduous trees also allow sunlight in winter while providing shade in summer.

But shading and natural ventilation alone will not adequately cool any building containing electronic equipment and more than 10 people; refrigerated air-conditioning is then necessary. Good climatic design should not be ignored, even though it can only reduce the load and not eliminate it. The high humidity means that evaporative cooling methods are not effective; in some locations, dehumidification of cooled air is a necessity.

Prevailing winds are primarily from the west and southwest, flowing against the coriolus effect of the rotating earth. Available wind energy depends more on terrain than in the cooler

guidance SOUTH TEMPERATE/2 Building Layout

climates, but hybrid wind-solar systems may be the most feasible. Buildings should be oriented with larger openings to the south and east so that cooling summertime breezes will be pulled through. (7) C-5

b. Conservation measures (171) 16-17

Design and site buildings to balance the effects of seasonal thermal variations, promoting both winter warming and summer cooling in terms of seasonal solar orientation and prevailing wind direction.

1. Use deciduous trees to the east and west, allowing the warming winter sun to penetrate but shading from the hot summer sun.
2. Use roof overhangs that shield window areas on south-facing walls from the higher summer sun but admit the lower winter sun.
3. On higher buildings, use sun shades to control summer sun: horizontal sun shades over south-facing windows, "eggcrate"-type sunshades over east- and west-facing windows, and vertical fins on north-facing windows are most effective.
4. Use medium-color surfaces on exterior walls to balance the need for summer reflection and winter absorption of solar radiation; use light-colored roofs to reflect summer sun; use dark, absorbent colors only in recessed places protected from summer sun.
5. Use steeply pitched roofs on the winter windward side to deflect winter winds and reduce the exposed roof area directly facing these winds.
6. Protect building walls exposed to winter winds with evergreens, earth berms or mounds, fences, walls, or outbuildings that can serve as wind screens.
7. In appropriate buildings that will not be air-conditioned, encourage cross ventilation and roof ventilation by prevailing summer breezes for cooling during hot summer months. This can be accomplished by building orientation and window placement, roof and gable ventilation, and planting based on prevailing summer breezes.

2. Building layout (180) 161**a. Site selection**

Like orientation requirements, slopes east of south are preferable. A "warm slope" area is best, but lower and upper

guidance SOUTH TEMPERATE/2 Building Layout

inclined portions are acceptable if wind sheltering is provided. In warm periods, breezes should be utilized for cooling.

b. Site structure

An open and free layout of buildings which tends to merge with nature is preferred. The site pattern can exploit the possibilities of free arrangement. (See "Security Systems.")

c. Public spaces

Open lawns with grouped shade trees are desirable. Roads are best planned in the southwest direction to avoid winter winds and channel summer breezes. Walking direction can be arranged freely.

d. Landscape

Indoor and outdoor relationships in building design should be considered. The use of outdoor living areas can be extended for several months as adjuncts to interior areas, if these areas are designed properly.

e. Vegetation

Windbreaks are desirable to protect against winter winds from the northwest. Tree layouts, however, should not block prevailing south-southwest summer breezes. Evergreen trees are best for wind protection; deciduous, for shading purposes. Lawns near the structure are useful to absorb radiation. Shade trees are preferred on the east and west sides of residences.

f. General arrangement

Due to the large range of thermal conditions, the structure must both utilize radiation and wind effects and protect against them.

g. Plan

Freedom in the design is characterized by spatial connections of outdoor and indoor areas. Buildings should open to the south-southeast and be closed on the westerly sides.

h. Form, volume

Wings protruding along the north-south axis receive less "penalty" than in other zones. Therefore, cross-shaped or free building formations are possible. However, elongation in the east-west axis is preferable, with the optimum shape being 1:1.6. The effect of volume is not important.

guidance SOUTH TEMPERATE/3 Building Elements**i. Orientation**

Solar-air orientation of 17-1/2° east of south allows for a balanced heat distribution. The orientation of high buildings should be correlated with wind exposure.

j. Interior

Adequate cross ventilation must be provided. Humidity-producing areas should be separated from the rest of the building. Penetration is desirable; therefore, interiors should not be too deep.

3. Building elements (180) 162**a. Openings and windows**

It is important that window areas be arranged for internal heat balance. South-exposed glass areas work well on seasonal bases. Protection is needed from summer radiation. Openings should be screened, and they should be located to allow cross ventilation. Reduced openings on the westerly side are desirable. Single glass surfaces transmit, on the average, 10 times as much as the amount of heat exchange transmitted by uninsulated wall surfaces.

b. Walls

Avoid absorptive materials, or those affected by freeze-thaw action. Rain and moisture penetration is mostly on northwest exposures.

c. Roof

Eaves and gable must be ventilated, but openings might be closed in winter. An attic fan is also effective. Gutters should be able to carry 1 inch of rain off the total roof area in 15 minutes. Snow and rain pockets must be avoided.

d. Materials

1. The insulation index is 70°. The required insulation values relative to south are east-1.3; west-1.3; north-1.4; the roof-1.5.
2. Material on the west wall with a 6-hour time lag balances internal heat distribution.
3. A vapor barrier on the warm side prevents condensation.

guidance HOT ARID/1 Energy Conservation**1.a. Climate considerations (7) C-7**

A band of arid land girdles the globe at 30° north and south latitude. Climatologists have attributed this to the high-pressure zone of calm air, called the horse latitudes, which causes the major air currents, the trade winds and the prevailing westerlies, to diverge from the area. Since no winds bring moisture into the area, relative humidities are generally less than 30 percent. Annual precipitation is at most 20 inches but usually less than 10 inches. The only plant life is sparse grasses and succulent plants with a small surface-to-volume ratio to reduce water loss, large water-storing cavities, and extensive root systems for water collection. Only occasional oases or groundwater allow the comparatively dense growth of green leafy trees and bushes.

Because plants do not absorb and photosynthesize the intense solar radiation, the hottest temperatures in the world are recorded in the hot arid climates, even though regions closer to the equator receive more sun. Also, without the insulating effect of vegetation and moist air, daily temperatures can vary by as much as 30°F, or twice that in regions with more vegetation. Seasonal temperature variations are also relatively large: building designs must accommodate 100°F or more in summer and below freezing temperatures in winter.

At higher elevations and latitudes, winter snowfalls melt and run off with the spring thaw, providing water for streams, rivers, and the irrigation of arable land. Because of the infrequent snow and rain at average elevations, there is no groundwater table except near permanent streams or the few places where clay soils have trapped water pockets. This means that frost action is limited to depths less than 2 feet, simplifying foundation design. Also, earth-sheltered or underground buildings can be built without the problems of groundwater pressure. However, electrical earth grounding is hampered by the dry soil, because groundwater is the electrical conductor that connects to zero potential. Thus injections of copper sulfate around grounding spikes are needed.

The dry air and almost tropical latitudes mean solar energy collection and conversion. Since more than 70 percent of the potential radiation is available all year long, solar energy can be a reliable source for photovoltaics or hot water. Passive solar with storage should be sufficient for heating on a well-designed and insulated building, but backup systems are recommended. However, more than half of the energy requirement for climate control is for cooling. Even though evaporative cooling is effective in the dry air, climatic designs should also include massive walls and shading of the entire structure. Solar arrays may double as shading devices.

guidance HOT ARID/2 Building Layout**b. Conservation measures (171) 17**

Design primarily to minimize building heat gain by solar radiation while maximizing shade and encouraging humidity in outdoor spaces around buildings.

1. Utilize densely arranged and shaded layouts of buildings, compact building shapes, and shaded walkways and courtyards.
2. Avoid paved ground surfaces which hold heat and produce sun glare.
3. Use light-colored walls and roofs that reflect solar radiation; use dark colors under overhangs to reduce solar reflection into building interiors.
4. Shelter windows from direct solar radiation with sunshades, roof overhangs, and plants; avoid east- and west-facing windows that are difficult to shade from low sun angles; set windows high in walls to avoid ground-reflected solar radiation.
5. Incorporate water features in site development concepts to maximize humidity and the cooling effects of evaporation from water.
6. Utilize dense overhead planting to provide shade, slow evaporation, and hold humidity near ground level.
7. Minimize paved areas and maximize planted ground covers to promote humidity and reduce solar reflection and glare.

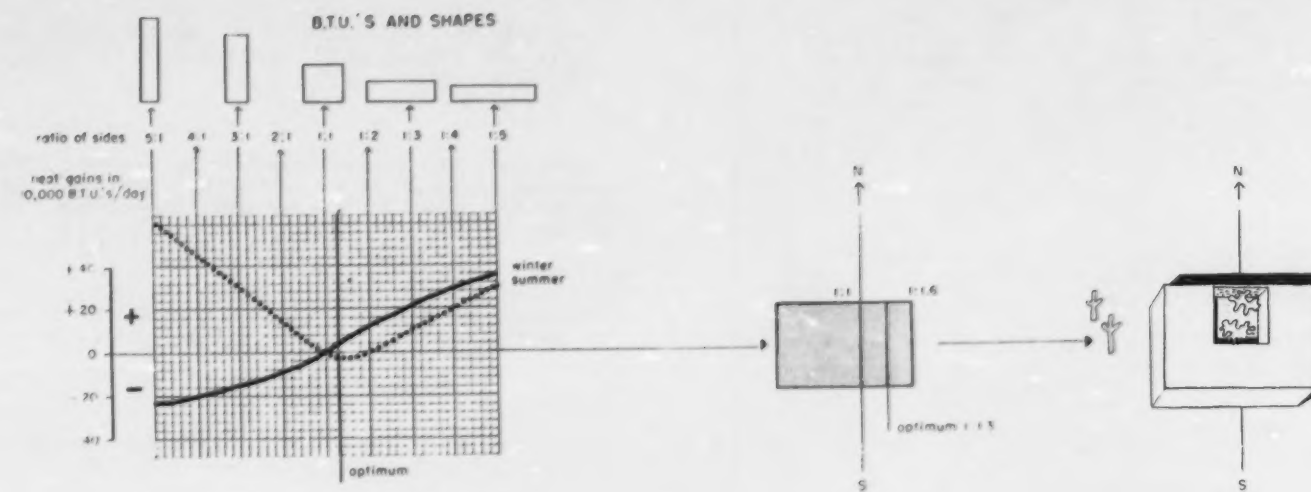
2. Building layout**a. Site selection**

Lower portions of preferred southeast-east slope exposures because of effect of cool air flow can be utilized and controlled. High altitudes, and locations with evaporative possibilities, are advantageous. (18) 167

The most critical issue in site selection is the availability of a reliable water supply. (58) 11

Summer air temperatures in Southwest Asia can range to 131°F and above. Winds are virtually unceasing, moving great volumes of hot, dry air and abrasive soil particles. Buildings should be grouped in oblong blocks oriented in an east-west pattern to minimize wall exposure to the sun. Where possible, buildings should include overhangs or arcades to provide additional shade. Building heights should be kept low and uniform to reduce wind turbulence. Street and open space patterns should be designed perpendicular to the wind. Elevation of roadways above surrounding terrain may mitigate some effects of the wind. When feasible, a barrier should be constructed around an installation to divert prevailing winds. (58) 111

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guidance HOT ARID/2 Building Layout**b. Site structure**

The walls of buildings and gardens should provide shade to outdoor living areas, similar to the effect of horizontal "eggcrate" devices. Unit dwellings or groups should create patio-like areas; concentration is desirable. The site structure should thus react against heat with a shaded and dense layout. (See "Security Systems".) (180) 167

Solar radiation beats down on desert regions with great intensity; it is seldom diffused by clouds. Summer air temperatures range up to 131°F (55°C) in the daytime, with night temperatures dropping to 77°F (25°C). Ground temperatures are typically much hotter than these air temperatures, but vary dramatically depending on the ground surface. The exposure of desert facilities to direct sunlight can be minimized by careful design of both the site and the buildings. Possible solutions include: (64) 47

1. Buildings

Buildings should be grouped into oblong blocks set in an east-west direction to minimize wall exposure to the low sun angles of the morning and afternoon.

Building forms should use large overhangs or arcades whenever possible to shade walls and openings. Traditional methods of shading buildings include using trees, using a double roof that encourages air movement between two surfaces and reduces the temperature of the actual roof, and clustering buildings to cast shade on each other.

2. Streets, walkways, and parking areas:

Streets should be as narrow as practical, and building setbacks should be minimal so that the buildings can shade a good portion of the walks and streets for most of the day. (64) 47

The construction of roads and airstrips is fairly simple in sandy deserts. Confined sand is an excellent foundation and makes a good-wearing road or runway when mixed with asphaltic products and the aggregate that forms the desert's surface. Asphalt is recommended for two reasons: a better-wearing coat can usually be obtained with the available aggregates when asphalt is used instead of cement, and, more important, asphalt uses considerably less water. Also, it is easier to handle asphalt for the same surface coverage. (64) 47

Properly aligned roads and airstrips will allow the wind to scour the surface and keep it free of drifting sand. The amount of elevation required can be determined only by

guidance HOT ARID/2 Building Layout

studying local sand drifts and the direction of prevailing winds. However, the elevation must not be more than a few inches; otherwise, wind might erode the sand that supports the surface, leading to pavement failures. (64) 48

Parking areas should be at least partly shaded to prevent excessive heat buildup. Shade can be provided by canvas, mats made out of local materials, building overhangs, and so on. (64) 47

Only the major streets or roadways should be paved. Walks and parking areas should consist of light, coarse materials. (64) 47

c. Public spaces

There should be a close connection between public spaces and residential areas. Half- and full-shade protection is desirable; paved surfaces should be avoided; pools of water are beneficial. (180) 167

d. Landscape

As vegetation is generally sparse, concentration of plant- and grass-covered areas in the manner of an "oasis" is desirable. (180) 167

e. Vegetation

Vegetation is desirable both to absorb radiation and for its evaporative and shade-giving properties. (180) 167

f. General arrangement

Heat loss rather than gain is the objective. Therefore, closed building arrangements around green areas are preferable. These arrangements should utilize evaporative cooling effects and night out-going radiation losses. Lythosphere arrangements (subterranean utilization) can be used. High ceilings are not necessary. Outdoor or roof sleeping possibilities should be considered. (180) 167

g. Plan

An inward-looking layout can benefit from microclimatic advantages. A walled-in building arrangement can benefit from cool air pool effects. A single floor and a convenient plan with economy of movements avoids heat gain. Evaporative possibilities should be utilized. Heat-producing areas should be separated from other areas of the building. Uninhabited spaces should be placed on the west side to baffle the impact of the sun. (180) 167

guidance HOT ARID/2 Building Layout**h. Form, volume**

Compact shapes are preferable. However, these shapes should be somewhat elongated on an east-west axis; the optimum shape is 1:1.3. The effect of volume is important. Building forms should have minimum solar projection. (180) 167

i. Orientation

Exposures 25° east of south provide a balanced orientation, but all exposures from south to 35° east of south are good. For bilateral buildings with cross ventilation, 12° south of west axis is preferred. (180) 167

Wind in desert areas is practically unceasing and is a major climatic force which must be planned for in these regions. Because the wind moves great amounts of hot, dry air, it dehydrates the desert environment severely. In addition, the wind always carries fine soil particles which abrade building elements, clog mechanical devices, and accumulate on every surface. Because of its destructive potential, the wind must be lifted, deflected, and guided, yet simultaneously used as much as possible for ventilation. (58) 2-3

Possible solutions include: (58) 2-3

1. Buildings--The height of buildings should be kept as low and uniform as possible. Taller buildings among low-rise buildings will create turbulence and eddies.
2. Installations--Where feasible, for longer standards of construction some sort of barrier, such as an earth barrier, should be built around the perimeter of the installation to lift and carry the wind.

Storm drainage systems should not be built; instead, natural drainage patterns should be established. Also, buildings should be kept away from low points where there is the likelihood of ponding.

j. Interior

Deep room arrangements can be used as a cooling contrast to intense outdoor heat. "Cool" colors reduce heat reflection on interior surfaces. Being connected to patio areas has a cooling effect. (180) 167

The zoning of buildings according to different times of the day or different seasons has had a long tradition in arid climates. (190) 115 The use of light colors to reflect light is the most obvious way to cool a building passively. (190) 116

guidance HOT ARID/3 Building Elements**3. Building elements****a. Openings and windows**

1. Relatively small openings reduce intense radiation. Windows should be shielded from direct radiation, and set high to protect from ground radiation. Openings should be closed tightly to protect against high diurnal heat. External shades are preferred. Openings should be located on the south, north, and to a less degree, the east sides. (180) 168

The recessing of entrances under arcades, the placing of windows flush with the inner face of thick masonry walls, and the protecting of openings with louvered shutters and carved screens all reduce the amount of solar radiation entering a building. (190) 116

Exterior doors and windows should be sealed as much as possible. However, no attempt should be made to erect a sand-tight building under normal service conditions because this cannot be done. (58) 6-5

Recent findings have shown that two equal-sized windows at opposite sides of a room will allow the maximum volume of air to move through a room. A smaller inlet and larger outlet window will decrease the volume but increase velocity, and with it, the rate of evaporation. The lower the inlet, the cooler the air drawn in and the cooler people will feel. On the building exterior, an overhang or a vertical fin at a window with a continuous slot between it and the building will funnel air into the window while equalizing the air pressure and increasing air movement. When the prevailing winds are not parallel to a window, a horizontal opening rather than one square or rectangular in shape will increase air flow. (190) 117

2. Infiltration of dust can be reduced by using: (58) 6-5

- o Nonoperable windows.
- o High air intake louvers.
- o An inertial dust separator.
- o Air filters.
- o Positive interior air pressure in the building.

3. Vestibules can be used to reduce dust penetration in air-conditioned buildings where sensitive equipment is stored. (58) 6-5

4. Use either horizontally pivoted (awning and hopper) or vertically pivoted (casement) windows to reduce maintenance problems. (58) 6-5

guidance HOT ARID/3 Building Elements

5. Do not use sliding windows because sand and dust accumulate in tracks during dust storms. (58) 6-5

b. Walls

Foundation walls should have insulation on at least one face and preferably two. This not only prevents the wall from acting as thermal bridge, it insulates the ground under the building from outside temperature swings that affect the subsurface temperature several feet below grade. Once insulated, the ground under the building will maintain an average temperature of around 70°F, which will help moderate indoor temperatures if the floor slab remains uninsulated. (190) 115

Walls of daytime living areas should be made of heat-storing materials; walls of rooms used at night should be of materials with light heat capacity. The east and west walls should preferably be shaded. High reflective qualities are desirable for both thermal and solar radiation. (180) 168

1. Interior walls (58) 6-3

Interior walls should be used as little as possible because they limit the air flow when windows are opened.

Where needed, interior walls should be lightweight and light in color.

2. Exterior walls (58) 6-2

Build exterior walls with massive earthen materials, such as adobe bricks, if feasible. By their nature and thickness, these materials absorb the heat and reradiate it slowly so that little is gained during the day. The ideal thickness of mud walls is 32 inches (80 centimeters). However, a minimum thickness of 16 inches (40 centimeters) may be used.

If lightweight wall systems are used, they should be insulated properly. Otherwise, they quickly absorb and transmit an intolerable amount of heat into the building's interior.

Shutter and/or shade wall openings during the daytime. Otherwise, these openings transmit a large amount of heat into the building's interior.

Keep the number of wall openings to a minimum.

Natural ventilation of interior spaces during daylight hours is not recommended. Tests have shown that if a room is ventilated throughout the day, its air temperature matches the outside temperature and remains high even after the outside temperature has dropped.

Ventilate at night, when the external temperature is low.

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The most effective height of windows to ventilate for human comfort ranges from 18 to 60 inches (46 to 152 centimeters) above the floor. In barracks, it is advisable to keep the sill at the height of the beds to insure an adequate airflow around this area. When higher windows are required, they should be horizontally pivoted so that the window panel deflects the airflow down into the space.

The surface of the external wall should be a light color or painted in light earthen colors to reflect high solar radiation.

c. Roof

The most important and often most difficult location for a high thermal lag assembly is the roof. The traditional masonry domes and vaults of Asian and North African architecture had good thermal lag properties because of their light color and rounded shapes, which reflected and dispersed the sun's heat. A concrete deck with a light-colored insulated roofing system could serve much the same purpose today. When cost or construction rules out a concrete roof, a well insulated wood truss roof with a white shingle and 1 square inch of vent to 1 square foot of attic space will suffice. (190) 115

Generally, heat storage insulation is best; it uses the flywheel effect of outgoing radiation for daily heat balance. However, a shaded, ventilated roof is also possible, primarily over night-use rooms. A water spray or pool on the roof is effective. High solar reflectivity is a basic requirement; emissivity is essential for long-wave radiation. (180) 168

Use a double roof with an air space between layers to reduce solar radiation. A minimum of 12 inches (30.4 centimeters), or preferably 24 inches (60.8 centimeters) of air space is required. (58) 6-3

Insulation is recommended for lightweight roofing systems because it increases thermal time lag. (58) 6-3

Connections attaching the sheet metal roofing should permit a considerable amount of thermal movement to allow for temperature changes. Movement should not be transmitted to structural supports. (58) 6-3

Roofs should be painted white or whitewashed to reflect solar radiation. (58) 6-3

In windy areas it may be necessary to take extra precautions in fastening down roofs. Desert winds may reach the intensity of a hurricane, and in such areas standard high-wind precautions must be observed. These precautions include placing cables over roofs and fastening roofing materials twice when possible. (64) 49

guidance HOT ARID/3 Building Elements**d. Materials (180) 168**

The material most often cited for its thermal lag properties is adobe, although homogeneous walls of stone, concrete, or brick and wall assemblies of, for example, face brick, wood studs, and insulation can work equally well. (190) 115

The insulation index is 45°; the required insulation values relative to south are east-1.1; west-1.2; north-1.0; the roof-1.6.

Walls with a high heat capacity are essential to provide time lags for internal heat balance. The necessary time lags are: east-0 hours; south-10 hours; west-10 hours; north-10 hours or no lag; the roof-12 hours.

e. Shading devices (180) 168

Devices should be separate from the structure and exposed to wind convection.

f. Mechanical equipment (180) 168

Heat-producing equipment should have a high operating efficiency.

Electrical and mechanical system protection

Electrical systems--The high temperatures, wide range of temperature extremes, intense solar radiation, sand and dust storms, and corrosiveness of soils will increase failures of all electrical equipment. (58) 4-1 Possible solution: (58) 4-1

- Provide extra training sessions to operator/maintenance personnel, stressing the need to be prepared and the importance of caring for the equipment conscientiously.

- Prestock as many spares and spare parts as practical.

- Pre-apply a highly reflective paint coating to the roof or upper surface of the generator unit.

- If a temporary tent is used, a reflective fly over the tent will reduce heating due to solar radiation. The fly can be reversed in winter months when the temperature is below freezing and used on the inside of the tent to reflect the heat inward.

- Since power is critical to the mission, provide a standby generator which is cool and can operate for at least several minutes before overheating and activating the automatic thermal cut-off. Never attempt to bypass the thermal control, since excessive temperatures can cause catastrophic damage to the electrical generator set.

- Assure that all operator and maintenance personnel are made

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fully aware of the potential problems caused by sand and dust.

Electrical power distribution--When wire with plastic insulation is used in very hot climates where solar radiation is intense, the insulation may become so hot that normal handling can damage it easily. Damage normally results from flowing of the heated insulation. (58) 4-5

Possible solutions:

- Use insulation rated for higher temperatures.

- Protect cable from direct sunlight during storage, especially just before handling.

Special considerations--Plastic insulation may become hot enough to change shape, showing the contours of the enclosed wire stranding. However, this phenomenon can occur because of a relaxation of insulation molecules, without significant thinning of insulation material. Careful insulation is required to determine whether actual damage has occurred.

Most of the protective devices used--such as fuses, fused cutouts, time-delay fuses, circuit breakers, and motor control contactors--are affected by high ambient temperatures. Thus, solar radiation combined with high ambient air temperatures can cause tripping and electric circuit shutdown at less-than-specified current levels. This applies to all low voltage (480 volts and below) distribution equipment and motor control centers.

Mechanical system--The high alkali content of the water normally found in desert regions corrodes water distribution systems and evaporative air cooling units. (58) 6-11

Possible solutions:

- If necessary, treat water that will be used for evaporative cooling.

- Do not use evaporative cooling where water is at a premium. However, since evaporative cooling units are more economical, use them as much as possible in hot, dry regions if water is available.

- A traditional method using the same concept of evaporation cooling is a chimney-type structure with an opening designed to catch the prevailing dry winds. The winds are then funnelled down a shaft in which a large porous pot full of water is suspended. The water in the porous pot slowly drops to a grid on which charcoal is spread. The air passing over the porous pot and the charcoal absorbs the water vapor, and cooling takes place by evaporation. Both the air introduced into the interior spaces of the building and the water in the pot are cooled.

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guidance HOT ARID/4 Soil Related Problems

Pipelines--particularly temporary ones--are subject to leakage because of the great temperature variations. On all lines, especially long ones, heat expansion must be considered. Since the temperature drops drastically at night in many desert locations, the diurnal temperature ranges may be considerable. Unless expansion is provided for, pipelines can break. (58) 5-16

All lines should be placed underground, if possible. This provides some insulation and prevents uncontrollable or excessive expansion of the lines. Cover should be about 18 inches when possible. Deeper coverage is not warranted unless the line is in a concrete envelope for protection from equipment. Lines should be well marked, particularly in sandy areas, to make inspection and repair easier. (58) 5-16

g. Foundations (58) 6-1

Use an on-grade concrete slab for foundation, whenever possible, to take advantage of the earth's insulating qualities.

Raised foundations, whether of the point or the perimeter type, should be avoided. Unless the floors can be insulated properly, they will be exposed to the high diurnal temperature variation.

4. Soil related problems

An important consideration when using concrete below grade in most desert regions is the high mineral content of the soil. Because evaporation exceeds precipitation, rain does not have a chance to leach out soluble salts, such as calcium carbonate and calcium sulfate, requiring that a type 5 sulfate-resistant concrete be used with a minimum amount of tricalcium aluminate in the mix.

Another characteristic of desert soil is its impermeability. The desiccation of the desert through evaporation often results in a lime-gypsum crust forming on the ground's surface. This crust can absorb little water, demanding that building drainage be channeled, collected, and adequately disposed of. With water shortages a perennial occurrence in arid climates, the collection of rainwater into holding ponds or storage tanks has become increasingly common.

The problems with desert soil are among several issues that affect specifying and detailing buildings in arid climates. Some of those issues include thermal movement, where daily temperature swings require a greater number of expansion joints, greater tolerances in cladding connection details, and greater attention to the joining of dissimilar materials; air infiltration, where frequent dust storms require care in weatherstripping doors, sealing windows, and filtering air intakes for mechanical equipment; and construction quality control, where the hot, dusty environment requires special precautions when pouring and curing concrete or when installing prefabricated components. (190) 118

guidance HOT ARID/4 Soil Related Problems

Extreme environmental factors such as high temperatures, haze, winds, and sand storms can degrade sensor performance by creating excessively high false alarm rates, reducing effective detection ranges, and causing mechanical and electronic component failures. Sandstorms can even bury a sensor completely. Infrared sensors are affected adversely by haze, ground fog, or sand storms. When the temperature is high, detection capabilities are reduced because the temperature differentials between target and background are small. Extreme temperature fluctuations make it difficult to adjust the dynamic range of infrared equipment. The effectiveness of radar is reduced during sand storms due to reduced effective ranges and clogging of moving components (such as sweeping dishes) with sand. Acoustic sensors will be affected adversely by background noises created by high winds and blowing sand; these noises can "dog" or abrade microphones. Seismic sensors will be difficult to emplace and be less sensitive where bedrock is exposed. (58) 3-8 Possible solutions:

- Electronic components should be shielded from the sun and cooled.
- Verifying sensors should be used to reduce false alarm rates.
- Low-frequency radars should be used during sand storms (up to 10 gigahertz).
- When possible, terrain should be altered to extend effective ranges of sensors. (58) 3-8

Due to the corrosiveness of most of the desert soils of southwest Asia, electrical system components can become corroded. This problem applies mainly to ground system components and to electrical connectors, connections, and wire splices. (58) 4-15

TM 5-765 states that the Army may use either copper-clad steel ground or galvanized steel ground rods. If galvanized steel rods are used, the corrosion rates will be high. Where the ground wire or strap normally clamps to the ground rod, a potential problem exists because corrosion may cause the connection resistance to become too high. Thus, it is recommended that this connection be welded, brazed, or appropriately soldered. If none of these options is possible, then an anti-oxidant compound should be applied liberally over the connection. (58) 4-15

Insulation failures due to a process known as treeing have been observed in cross-linked polymer cables. The salinity and alkalinity of desert soils make such failures a problem in southwest Asia. In general, treeing has been noticed more with high voltage cables (13,600 volts and up), but is possible in lower voltage cables. Water treeing occurs when the cable, in addition to being subjected to high voltage stress, is in a wet location. Most failures diagnosed as being treeing occur after cables have been in use for several years. Therefore, use cables with tree-resistant compounds incorporated. (58) 4-16

guidance HOT HUMID/1 Energy Conservation

1. a. Climate considerations (7) C-9

With little daily or seasonal temperature variation, temperatures generally around that of the human body, never below freezing, and a rainy season with 40 to 60 inches of annual rainfall, the equatorial jungles are a garden of life. For at least half of the daylight hours, the sun shines from an altitude of 60° or higher. This is because its position at the meridian varies from one side of the zenith to the other with the seasons, rather than from high to low as in nontropical latitudes. Seasonal temperature variations are thus reduced, but insolation levels are so high that without the protective cover of dense vegetation to adsorb and photosynthesize solar energy, temperatures would be much higher than in the arid climates.

It is important, then, to preserve the natural vegetation as much as possible during the construction process. Especially important are those plants that provide overhead shade. If natural vegetation is not preserved, the cooling load will be quite large. Vegetation also helps to provide a natural camouflage and absorb the impact of torrential downpours.

The optimum building shape is a rectangle with a length-to-width ratio between 1.7:1 and 3:1, oriented along the east-west axis. Most solar radiation falls on the roof, which collects heat per unit surface area and dissipates it per unit perimeter length. The long rectangular shape provides a large perimeter length-to-surface area ratio, which reduces heat collection, and increases dissipation. The rectangular shape also minimizes east and west wall surfaces that would collect heat, because whenever the sun is low in the sky it shines from an easterly or westerly direction. Earth berming against these walls is also effective in reducing heat gain.

Shading devices operate by first converting absorbed solar radiation into heat so that they become hotter than the surrounding outside air. The devices then dissipate the heat into the air. This means that the structure that supports the shading device must be separate from the building structure. Otherwise, the heat from the shading devices will be conducted through the structure into the building. Also, the devices must be designed to be cooled either by the ventilation of natural breezes or the convection currents they generate.

The recommended shading devices for this climate are large overhangs to the north and south. These overhangs should shade not only the walls and windows but also the surrounding horizontal exterior surfaces that reflect sunlight onto the walls, and vertical sun screens on the east and west. Large overhangs also protect the building from rain, which may fall at a 45° angle. If possible, the roof and overhangs could form an entirely separate structure over the building itself, with an airspace in between, similar to a tent fly over a tent. This secondary structure, if shaped to shed rain, need be only a lightweight fabric tension

guidance HOT HUMID/1 Energy Conservation

structure. Finally, solar arrays may again double as shading devices.

Because of the high rainfall and the resultant high water table, there are several difficulties with underground and earth-sheltered construction. Pitch and plastic film may not seal adequately against groundwater pressure. If not properly designed, entryways and light wells could fill with water and flood the building. As in the design for polar climates, floors 3 to 7 feet above the ground surface are recommended. However, it is possible to excavate the tropical soil, thus, when earth-sheltered designs are required, one solution is to mound the earth into a foundation surface above normal ground level and to continue to mound up around the completed building. The mounding soil would be a coarse-grained sand for good drainage, and soil-bearing pressures should be analyzed for the extra weight of the mound.

One problem in tropical design is dealing with insect and animal life and with the fungi that grow in the hot-humid air. Windows and doors that are opened for ventilation must be screened against insects, which can be harmful to equipment as well as personnel. Insects and fungi can destroy wooden and plastic structures, and equipment; they must be treated with insecticide and fungicide. Shields must be constructed to deflect wood-eating insects. Because snakes can find their way through small cracks, all joints must be sealed to prevent hazards to personnel. To prevent the growth of fungus on interior surfaces or equipment, all spaces should be well ventilated, and the air should be dehumidified.

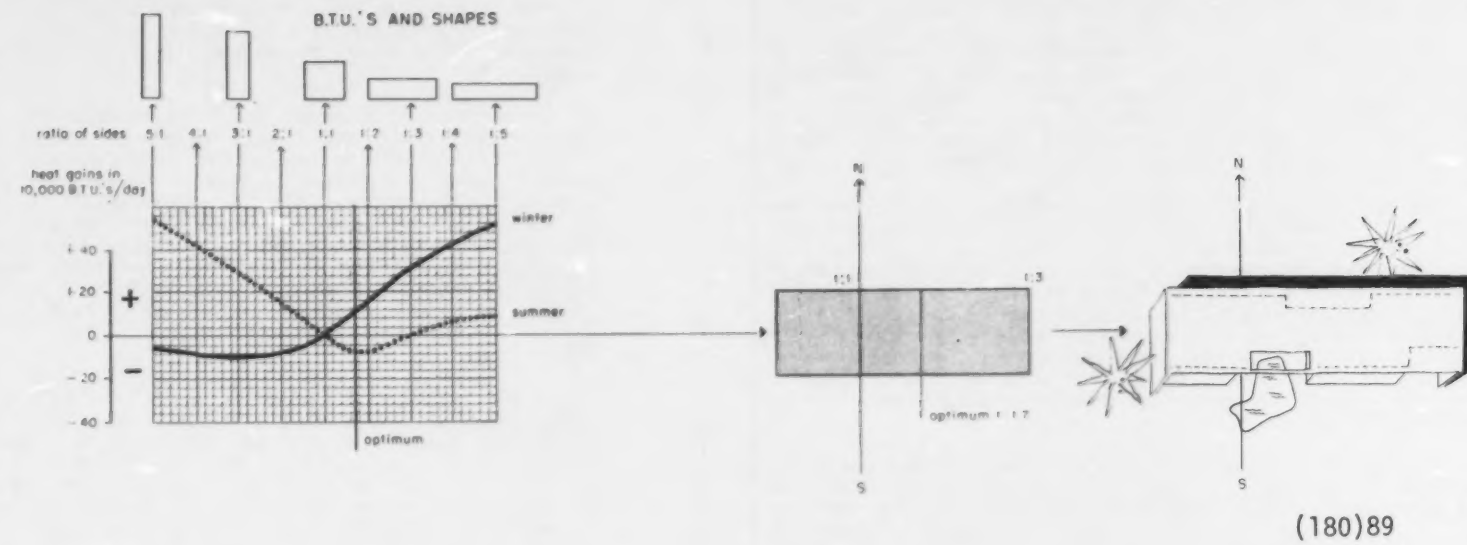
Because evaporative cooling is ineffective in high humidity, refrigerated air-conditioning is necessary to maintain an interior temperature below 78°F. Cooled air must be dehumidified or condensation will occur. Vapor barriers are required on exterior as well as interior surfaces. Because refrigerated air-conditioning is energy consumptive, all shading techniques should be applied to reduce the load. Finally, heating requirements are minimal (fewer than 40 hours/year require moderate heating). Thus, only temporary space heaters, not permanent central heaters, are required. Reversing the heat pump in the air-conditioner could provide the heat source.

b. Conservation measures (171) 18

Design primarily to minimize building heat gain by solar radiation while promoting air movement and cross ventilation for comfort from humidity.

1. Maximize shade throughout the day, to reduce both solar radiation and sun glare.
2. Use window sunshading devices that provide protection from solar radiation but encourage air flow; minimize east- and

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guidance HOT HUMID/2 Building Layout

west-facing walls and windows where it is difficult to control low sun angles.

3. Use roof overhangs for sun screening and protection from rain and sun glare; use trellises as effective sun and glare control devices.
4. Utilize light-colored roofs to reflect solar radiation.
5. Shade outside walkways with trees, building canopies, or arcades.
6. Encourage closely located but physically separated building arrangements that promote air movement between buildings.
7. Orient streets and buildings to maximize cooling breezes; use vegetation to channel cooling breezes.
8. In non-air-conditioned buildings maximize roof ventilation and cross ventilation of living and working spaces.
9. Maximize openings and windows that promote cross ventilation.
10. Select building sites near the crest of hills or on the windward side of ridges to maximize wind flow.
11. Use high-branching site vegetation that provides shade but allows cooling breezes to pass near ground level; avoid low vegetation that blocks air movement into and around buildings.

2. Building layout**a. Site selection**

High elevations on the windward side are desirable. Specifically, locations near a crest slightly offset from the prevailing wind direction receive the most air movement. Southern and northern slope directions rather than the east and west sides are preferred because of less radiation. (180) 173

b. Site structure

The accent should be on separated buildings to take advantage of air movements. A shaded environment becomes an important consideration. The site fabric should be loose and scattered. (180) 173

c. Public spaces

Minimum walking distances and shaded areas are preferred. (180) 173

guidance HOT HUMID/2 Building Layout**d. Landscape**

In generally flat areas, the integrated use of water is both possible and desirable. Water drainage must be provided away from the building. Grading must be provided for run-off of intensive rainstorms. (180) 173

e. Vegetation

Shade trees should be high branching so that they do not interfere with breezes. Low vegetation must be kept away from buildings so it does not block air movement. Air coming into a structure from across a shaded lawn is desirable. (180) 173

f. General arrangement

Buildings should be shaded structures which encourage cooling air movements; shade protection should be on all sun-exposed sides, mainly on the roof and the east and west exposures. (180) 173

g. Plan

If temperatures are not too excessive, free plans can be evolved as long as the building is under protective shade. There should be a free air path through the interior. The plan might be organized into separate elements, since 75 percent of the time outdoor conditions are nearly comfortable, if shaded. Paving should be avoided. Screened areas are necessary to keep out insects. Roll-back walls are useful. Heat- and moisture-producing areas should be ventilated and separated from the rest of the structure. Vapor, insect, and humidity control is necessary in storage spaces. (180) 173

h. Form, volume

Strong radiation effects on the east and west sides should dictate the shape of buildings to a slender elongation. The optimum shape is 1:1.7, but up to 1:3.0 on the east-west axis is also acceptable. An effect of volume is undesirable. (180) 173

i. Orientation

Solar-air orientation is balanced at 5° east of south, with relatively small deviation from it (10°) to remain desirable. Orientation with the long side toward differing wind directions is acceptable only under shaded conditions. (180) 173 Orientation in a warm-wet climate helps provide the best possible ventilation; therefore, the direction of the prevailing winds should be studied carefully. Contrary to common belief, this does not mean that the wall with the inlet windows should directly face the prevailing winds--satisfactory ventilation conditions can be achieved at angles of up to about 50° on either side of the wind direction. The direction of storms should also be taken into consideration in order to minimize their impact. (65) 353

guidance HOT HUMID/3 Building Elements

Open planning and wide, free spaces between buildings help to achieve good ventilation. (65) 353

j. Interior

Interior spaces must be shaded and well ventilated. Flexible spaces, by the use of screened, movable, or low partitions, are desirable. Floor materials must be impervious to moisture. Daytime living areas should allow the flow of east to west winds. A safe area is necessary during hurricanes. (180) 173

3. Building elements**a. Openings and windows**

The customary distinction between walls and openings disappears in a hot-humid climate. Ventilation is needed 85 percent of the year; east-west cross ventilation is essential. Roll-back opening walls are practical. Elements such as screening, louvers, jalousies, and grills admit air flow and protect from the sun. The structure must be sheltered from sun, rain, sky radiation, and glare. Removable shutters are desirable for hurricane protection. (180) 174

The large area of opening required in a warm-wet climate necessitates adequate shading. Otherwise, indoor temperatures may rise appreciably above those outdoors. Shade is required not only against direct solar radiation, but also against diffused radiation from the sky, which in tropical regions may be very intense. (65) 354

In many cases solar protection may be combined with rain protection, not only with respect to the windows but also for the whole area of the walls, by extending the roof beyond the floor area. This is more necessary in warm-wet climates, where tropical rains are very heavy and are wind borne. The almost-horizontal wind-driven rain penetrates through joints and cracks in the walls and windows. Unprotected walls may become saturated, and the rapid succession of wetting and drying speeds up deterioration of their component materials, especially on the external surfaces. (65) 354

Fly-screens are essential in most warm-wet regions, but they may reduce air flow appreciably. To minimize their blocking effect it is best to install them at some distance from the wall, rather than directly on the windows, and extending over a much larger area than the windows. (65) 354

Ventilation--Large openings, doors and windows, are advantageous in a warm-wet climate provided that they are protected effectively from solar radiation, driving rain, and insects. The advantage of large openings is not only that they ventilate, but also that they enable lower temperatures to be

guidance HOT HUMID/3 Building Elements

achieved during the night. (65) 353

b. Walls

Walls are less important here than in any other region. They are used primarily for screening from insects and for their flexible wind penetration qualities, rather than as thermal batteries. Folding window-wall solutions are possible. (180) 174

c. Roof

The design emphasis should be here since the strongest thermal impacts occur here. A ventilated double roof is desirable; the upper roof functions as protection from the sun. It must be watertight, insulated, and reflect solar rays. A wide overhang is necessary to protect against rain and to reduce sky glare (the rain often comes at a 45° angle). (180) 174

Because of their low heat capacity, lightweight roofs, covered with tiles or sheets of asbestos-cement or aluminum, are preferable in a warm-wet climate. But such roofs, which are usually dark in color, or at any rate not whitewashed, are heated by solar radiation and may cause heat stress during the daytime. Therefore, thermal insulation either at the ceiling level or beneath the upper roof layer is recommended. An effective means of insulation is to place aluminum foil underneath the roof in order to reduce the radiant heat flow from roof to ceiling. This may be supplemented by an insulating layer above or beneath the ceiling and by ventilation of the attic space. (65) 356

Double roofs consisting of two layers with a ventilated air space are desirable not only because of their solar-protecting quality, but also because of the protection they offer from the rain. Care must be exercised, however, in insuring their resistance to the lifting power of stormy winds. (65) 356

Ventilation of the attic space without adding insulation is inadequate, since the main heat flow from roof to ceiling is by radiation. (65) 356

When concrete roofs of high heat capacity are constructed, it is preferable to provide an insulating layer below the ceiling. This reduces heat flow during the day and enables rapid lowering of the ceiling temperature during the night. (65) 356

d. Materials (180) 174

1. The insulation index is 35°; the required insulation values relative to south are: east-1.4; west-1.5; north-1.1; the roof-2.3.
2. Light heat capacity walls are best: thermal lag may cause night reradiation of heat and morning condensation.

guidance HOT HUMID/3 Building Elements

3. It is necessary to prevent the deterioration of materials by moisture and animals.

Because of the permanent ventilation requirements and the small outdoor diurnal temperature range that characterize the warm-wet climate, it is not feasible to utilize the heat capacity and resistance of the walls to reduce the daytime temperature below the outdoor level. Therefore, the main criteria in choosing materials are prevention of daytime indoor temperature rise to above the outdoor level, and minimization of such elevations during the evening and night hours. Other factors concern the weathering qualities of the materials in a damp and humid environment, and the likelihood of biological attack by insects (such as termites) and fungi. The heat capacity of the building should be as low as possible in order to prevent accumulation of heat during the night, when the external wind speed is usually lowest. (65) 355

When heavyweight materials must be used for structural reasons, the effect of heat capacity can be minimized by covering the materials with an insulating layer. This maintains the surface temperature very close to the surrounding air temperature. For instance, when concrete floors are used in multi-storied buildings, the corresponding ceilings may be covered by a layer of insulating material so that their temperature at night follows the air temperature closely. (65) 356

e. Shading devices

Sunbreakers are important because of powerful radiation, mainly on east and west sides. It should also be noted that the north wall gets more radiation impact in summer than does the south wall. (180) 174

The shading devices should not reduce air velocity within the occupied zone. It should be possible to open horizontal adjustable louvers at an angle of approximately 120° , so that when required they direct the air flow downwards toward the occupied zone. In multi-storied buildings, window overhang shades tend to reflect an appreciable amount of solar radiation onto the walls and into the windows of the upper stories. On the other hand, incline slats running parallel to the wall between horizontal beams projecting from the walls can provide fully effective shading while at the same time reflecting the sun's rays outwards, enabling free air movement over the external surface of the walls. Such slats can be made of such materials as precast concrete, asbestos-cement, wood. They allow better illumination than do solid overhangs, but provide less protection from driving rains. (65) 355

f. Mechanical equipment

Forty hours of the year require moderate heating, with approximate thermal differential between the indoors and outdoors

guidance HOT HUMID/3 Building Elements

of 25° to 30°F ; 1250 hours require low heating (the average daily differential is 5° to 10°); and 940 hours have no special requirements. During 6650 hours of the year, cooling would be desirable. However, such installation with its high cost is in sharp contrast to normal outdoor conditions. Mechanical ventilation with fans would be effective. Domestic solar water heaters are a possibility. (180) 174

A dehumidification system may be required for a facility located in a very humid climate. (19) Vol 2, 8

Some locations have extremely adverse atmospheric conditions--such as hot, humid tropical climates, salt-laden marine atmospheres, and atmospheres containing substantial quantities of corrosive, abrasive or irritating pollutants. In such areas, consideration should be given to air-conditioning solid state UPS and battery areas rather than cooling by forced ventilation, which usually involves high rates of outdoor air circulation. The recommended temperature limits should be obtained from the equipment manufacturer and should be used to design the environmental control system. (19) Vol 2, 8

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